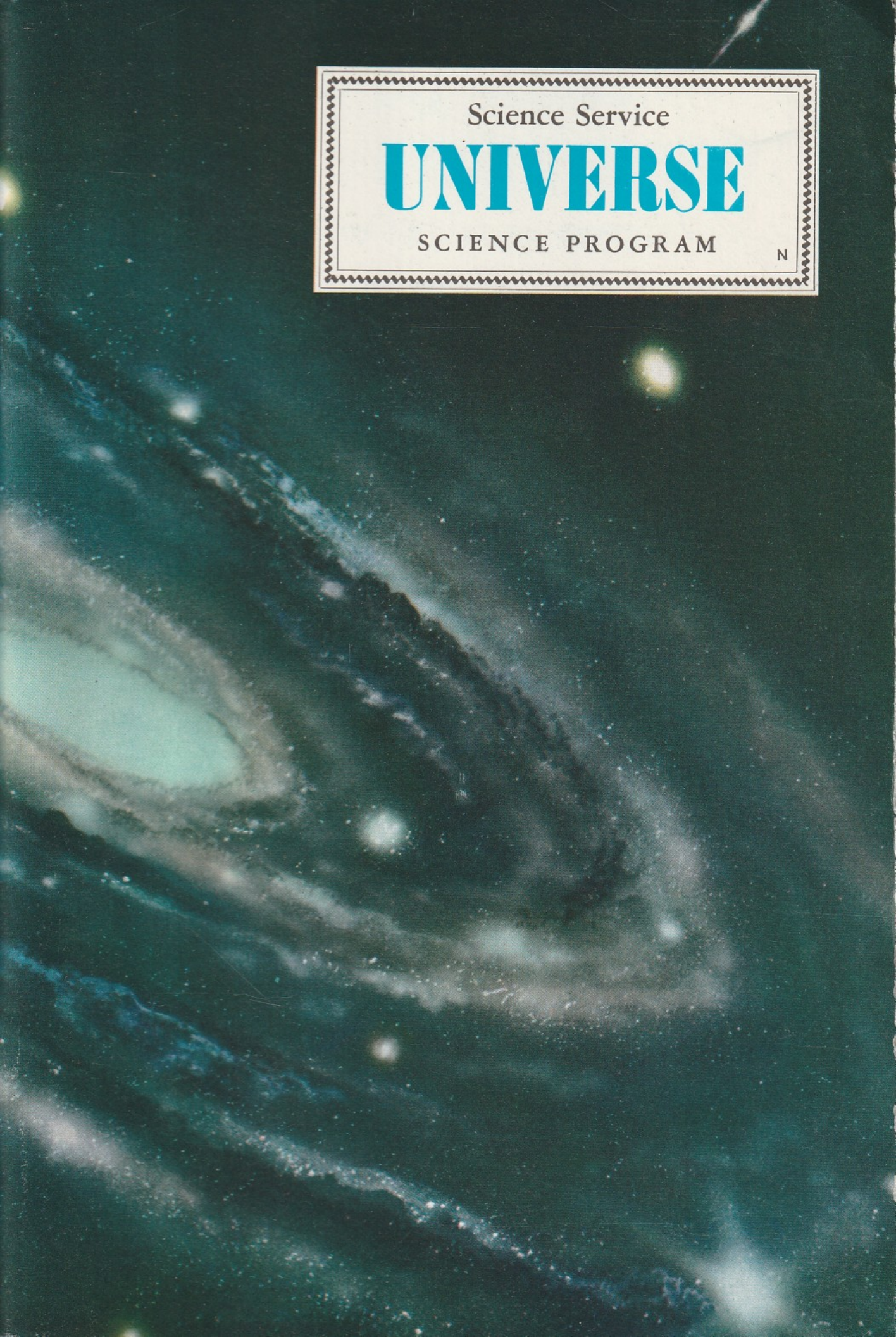

Science Service

UNIVERSE

SCIENCE PROGRAM

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THE NATURE OF THE

UNIVERSE

SCIENCE PROGRAM

Prepared with the co-operation of
Science Service

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The comet Kohoutek streaking through the firmament in 1974.

The Nature of the Universe

NO SIGHT IN ALL NATURE is more impressive and more beautiful than the star-studded firmament of the heavens.

In ancient days when there were no street lights to dim the brightness of the stars, or smoke from industrial cities to veil their grandeur, it was natural for men to gaze upward and for thoughtful men to study heavenly objects and ponder about the meaning of the universe. Long before men made a habit of writing down their thoughts, there is evidence that they were making careful observations of the heavens, thinking out explanations for what they saw and devising methods for predicting what would occur in the future.

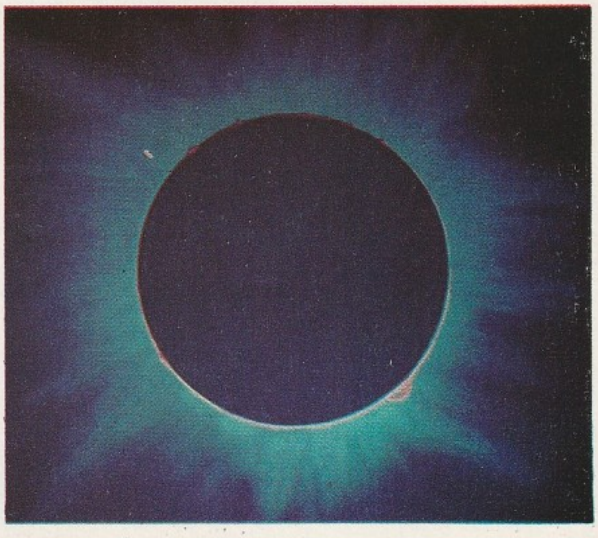
With the passing of the years, these earliest theories had to be revised to accord with more precise observations, just as astronomers today are constantly revising their theories to conform with the latest observations made with the help of the most advanced instruments. Such revision will continue in the future so long as the universe endures and men have the curiosity and wisdom to study it.

Among the first facts observed must have been the regularly recurring dawn and darkness, and the fact that the sun appeared in the morning in the east and disappeared from sight in the west. Another easily observed fact was the changing appearance of the moon as it went through its phases.

Ancient man also noticed the change, with the passing of the year, in the location of the rising and setting sun and the length of the shadows

A comparison of the large magellanic cloud as photographed (*left*) in the wavelength range by the Apollo 16 far-ultraviolet camera, and (*below*) in visible light with a ground-based astronomical camera.

A total solar eclipse provides one of our best opportunities to observe the corona, the outermost atmosphere of the sun. The black disc is the moon, which is passing between the sun and the earth.



1. A SOLAR ECLIPSE

cast at midday, and it was natural to associate these changes with the seasonal changes in vegetation.

By the year 4000 B.C. in Babylonia, and soon afterward in China, men attempted to determine the number of new moons in a year. By the year 2000 B.C., it had been calculated that the year contained 360 days—not so different from our present 365¼. The ancients also made adjustments, as we do with leap year, to make the calendar come out even.

Grouping of stars into constellations is believed to have been accomplished very early, perhaps as long ago as 4000 B.C. By the year 1100 B.C. it was known that the year's length is 365¼ days.

When the Great Pyramid was built in Egypt about 2900 B.C., it was oriented toward the star that was then the "pole star" and the sides ran north and south and east and west so accurately that their placement was off only about a twentieth of one degree.

Other ancient temples were so built that the rising sun at a certain time of year would shine right through them to illuminate an important interior feature.

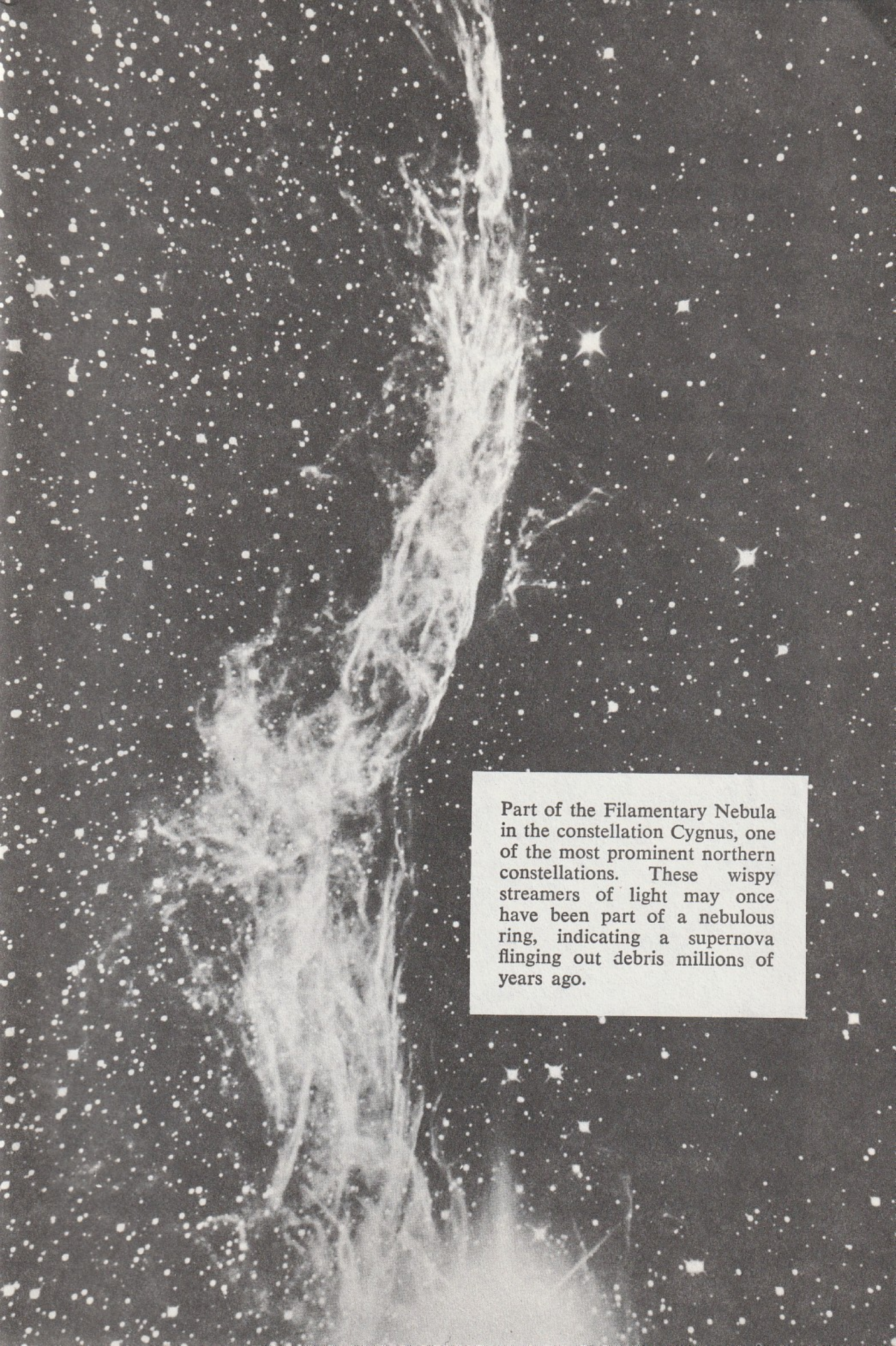
Although the ancients had no mechanical clocks, they developed some very ingenious devices to measure the time. Astronomers in ancient Mesopotamia are credited with invention of a water clock. In this instrument, water dripped through a hole in the bottom of a tank into a

The Orion nebula, photographed with a sixty-one-inch reflector, is an enormous cloud of interstellar gas which is illuminated by the light from four very hot young stars embedded in it.

lower vessel where a pointer on a float indicated the passage of time on a graduated scale. The sun dial was probably invented by the Babylonians and is also very ancient.

Astronomical instruments for observing the movement of stars and for the orientation of pyramids and other monuments probably date back in Egypt to 1355 B.C.

Astronomy in Egypt was put to very practical applications. Since the success of agriculture along the Nile depended on knowing when the great river would flood over its banks, one of the important duties of the priest-astronomers was to predict this event, which occurred near the time of the summer solstice (when the sun is at its "highest point", normally on 22 June). Pointing their monuments in the direction of the



Part of the Filamentary Nebula in the constellation Cygnus, one of the most prominent northern constellations. These wispy streamers of light may once have been part of a nebulous ring, indicating a supernova flinging out debris millions of years ago.

rising sun at the summer solstice made it possible to use these monuments as astronomical instruments in making the prediction.

Astronomy was advanced in very early times in China. About 2650 B.C. the Chinese had built a sphere to represent the motions of celestial bodies, a prototype of our modern planetarium. And also about 2650 B.C., the emperor Huang Ti ordered official astronomers to make the necessary observations of sun, moon and planets in order to reform the calendar.

The tradition of amateurs making considerable contributions to astronomy seems to date far back in time. The man credited with founding Greek astronomy, Thales of Miletus, was just such an amateur, a businessman who in the course of his trade visited Mesopotamia and Egypt and learned what was known of astronomy there. This enabled him to predict an eclipse of the sun in about 585 B.C.—although some say there is doubt about the authenticity of this report.

Ancients had difficulty understanding an eclipse of the sun. Today eclipses are not only understood, but tracked and photographed in multiple exposure.

Thales is believed to have known the length of the year, the positions in the sky of the signs of the zodiac, and the solstices and equinoxes. He understood that an eclipse of the moon is caused by the shadow of the earth, and an eclipse of the sun is caused by the moon coming between the sun and the earth.

But the Ionians, ancient Greek philosophers, still retained many old, fanciful ideas about the universe. They believed that the earth was flat and the stars were in fixed positions in the dome of the sky—as some said, like nails stuck into a solid sky. Their ideas of the sun and moon were very fanciful, too.

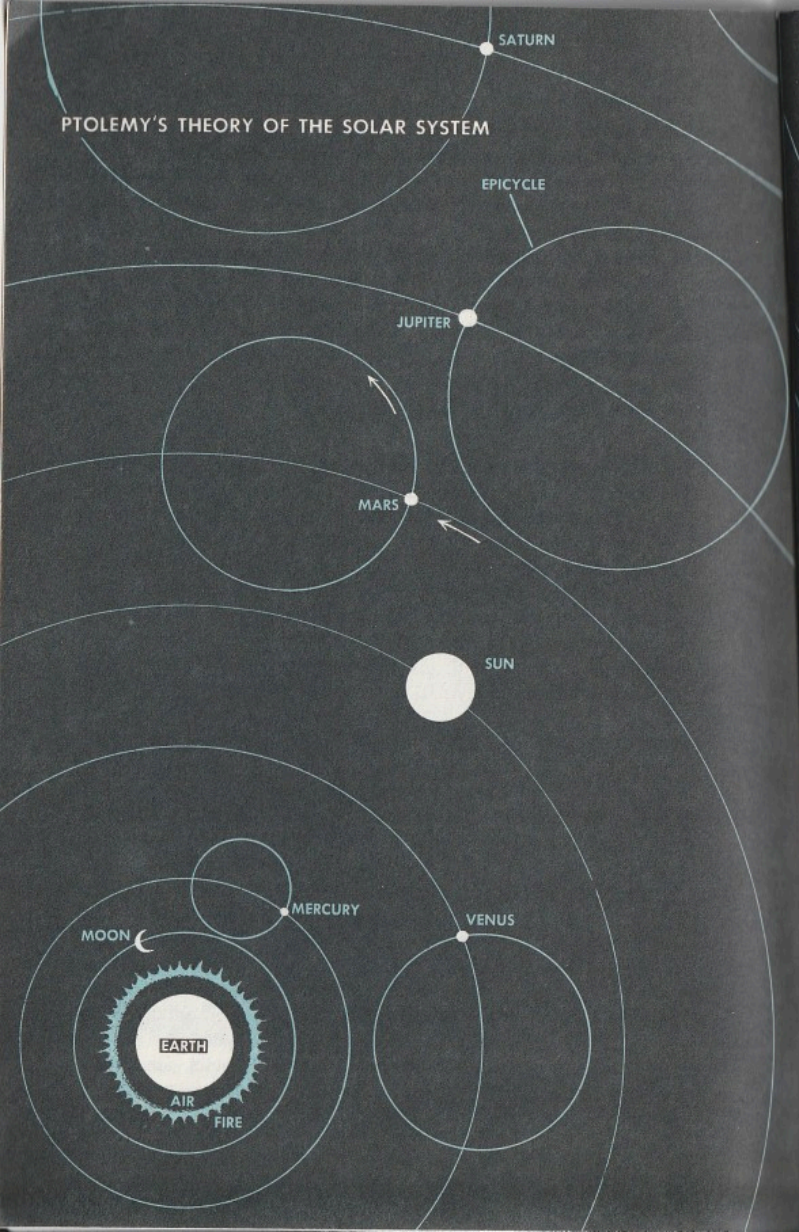
A Sky Full of Stars

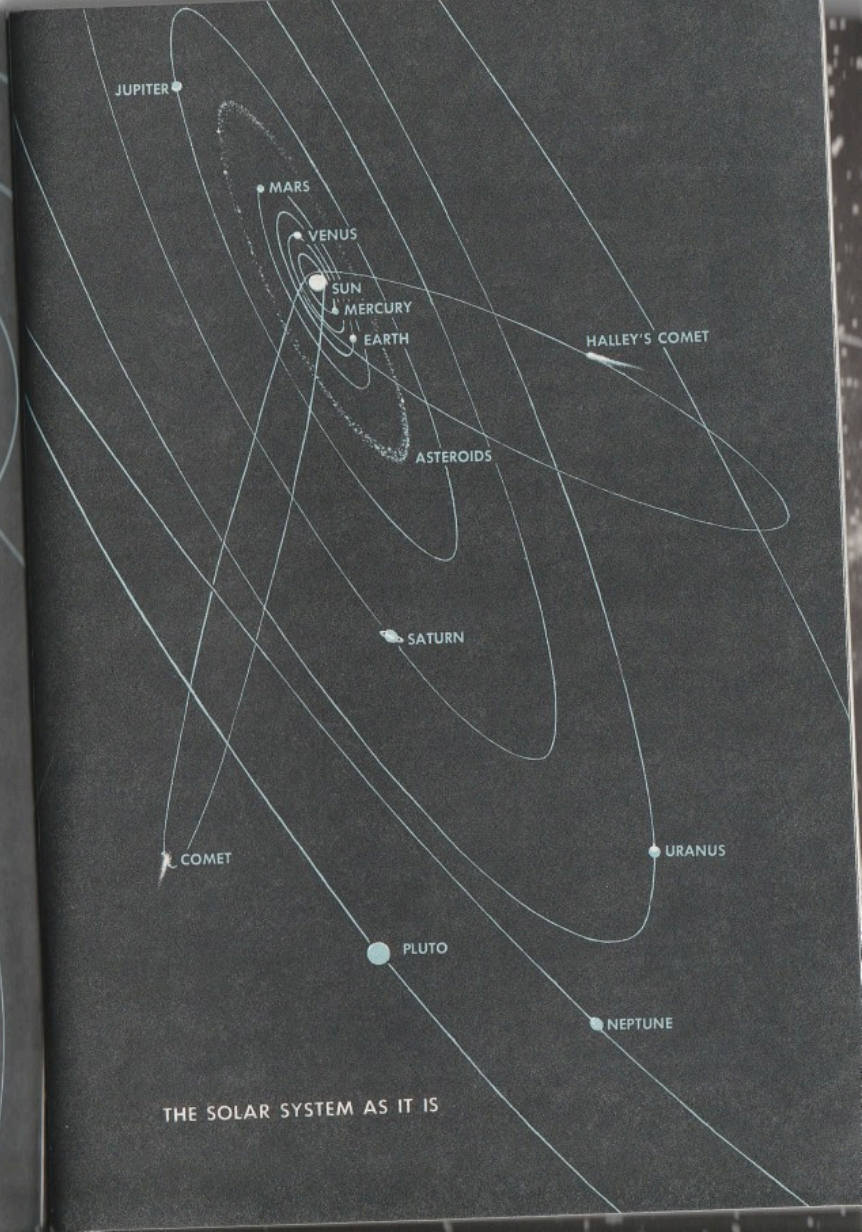
AS WE ALL KNOW, the stars can be divided into groups called constellations—the Great Bear (a part of which is known as the Big Dipper); Draco, the dragon; Cassiopeia; and many, many others.

Nearly all of the star groups we use today were named several hundred years ago and come from Greek and Roman myths. They represent dragons, giants, serpents and many other creatures. The idea that these star groups are supposed to look like their namesakes has baffled many a stargazer. Take Orion, the hunter. This group of stars is pictured as representing the great hunter with his club raised to strike the onrushing bull (in the next constellation). It does not look that way to many people.

Constellations help us find the stars we want to observe. Instead of trying to point to a star several millions of miles away with your finger, which is about three inches long, it's much easier to say, "The star I'm talking about is the bright one that forms Orion's left shoulder." In other words, the constellations are much like a road map. Their outlines are like the boundaries of states and countries, and their individual stars are like the map's dots which represent towns and villages.

Nearly 2,000 years ago a man named Claudius Ptolemaeus of Alexandria—or Ptolemy for short—gave the world a great astronomical treatise called the *Almagest* (Arabic title meaning "The Greatest"), which may be considered the greatest astronomical reference work of antiquity. It was not wholly original, admittedly being based largely on the work of earlier scientists, particularly of Hipparchus, whom Ptolemy greatly admired. This work contained a catalogue listing 1,028 stars, apparently almost the same as those listed by Hipparchus. Astronomers now calculate


SATURN
PTOLEMY'S THEORY OF THE SOLAR SYSTEM
EPICYCLE
JUPITER
MARS
SUN
MERCURY
VENUS
MOON
EARTH
AIR
FIRE


JUPITER
MARS
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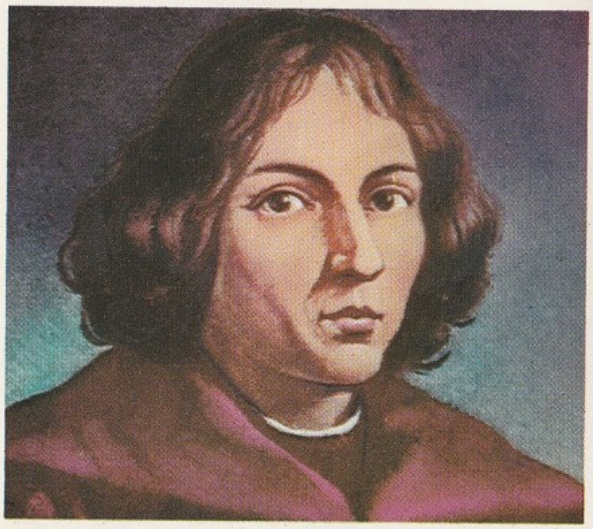
MERCURY
EARTH
HALLEY'S COMET
ASTEROIDS
SATURN
COMET
URANUS
PLUTO
NEPTUNE
THE SOLAR SYSTEM AS IT IS

that between 6,000 and 7,000 can be seen with the naked eye in perfectly clear weather, although not all at the same time and place. Ptolemy listed forty-eight constellations. Today astronomers recognize a total of eighty-eight, many of these added since 1600 to represent constellations visible only in the southern hemisphere.

Ptolemy also described the construction and use of an astronomical instrument, the astrolabe, for measuring the angular distances between stars.

Ptolemy knew that the earth is spherical, but he believed it to be the center of the universe and to be standing still. He also worked out an explanation for the motions of the planets, which, although discarded in later years, remained popular for many centuries.

Nicolaus Copernicus, born in 1473, conceived the theory of the solar system essentially as we know it today. His theory went far to overthrow Ptolemy's view of the universe.



2. COPERNICUS

The Slow Awakening

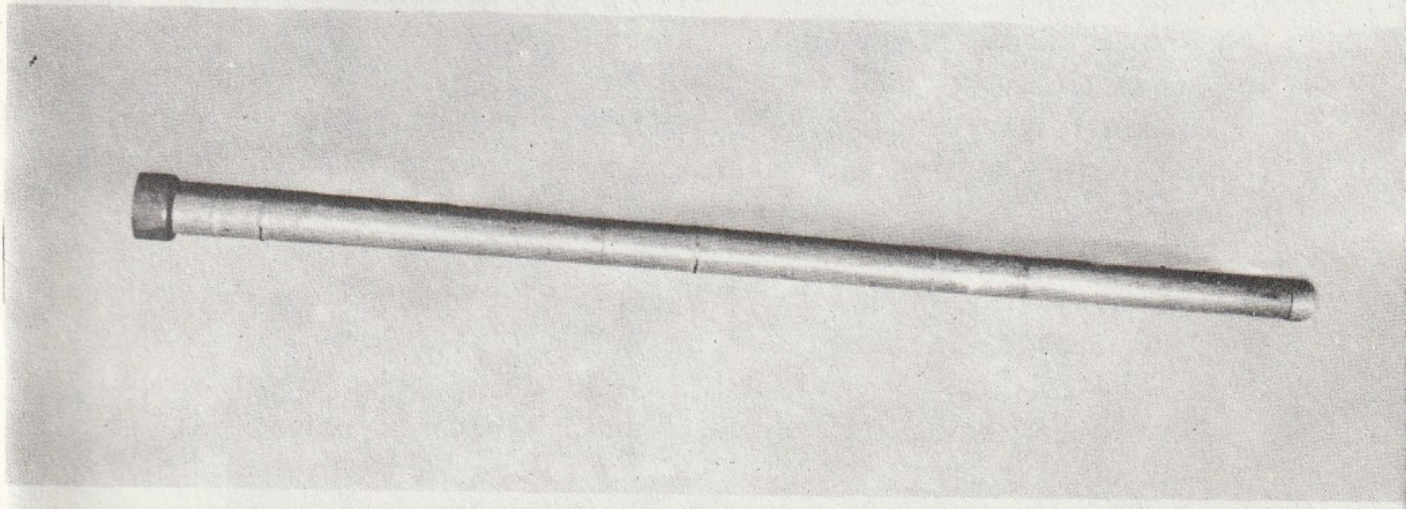
NEARLY 1,500 YEARS PASSED before anyone had the knowledge and courage to show that Ptolemy's thinking was wrong. The enlightened person to do this was Nicolaus Copernicus, a Polish scientist and, oddly enough, an officer of the Church. Copernicus studied at Cracow, Poland and at Padua, Italy. In 1499 he began teaching at the University of Rome. During this time Copernicus had been reading the

old theories of the Greeks as set down by Ptolemy. The more he read the more he was convinced that most of Ptolemy's thinking was wrong. In the year 1530, when Copernicus was fifty-seven years old, he completed what was then regarded as the most startling theory on astronomy ever written. Today his theory is considered one of the great contributions to science.

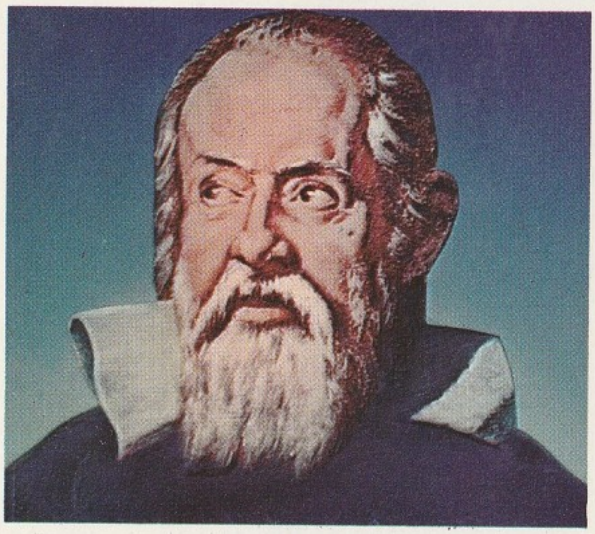
The sun, not the earth, said Copernicus, is the center of the solar system. The earth is nothing more than one of many planets circling the sun. The earth spins on its own axis and so accounts for day and night. Our seasons are caused by the earth's revolving about the sun. And the stars, Copernicus said, are great fiery globes so far away that we cannot begin to imagine their great distances.

In fear of a reprimand from the Church, Copernicus waited thirteen years to publish his findings. The title of his book was *On the Revolutions of the Heavenly Spheres*. As it turned out, there was little need for Copernicus to fear the personal consequences of a reprimand. He died a few days after his great work was published.

One of Copernicus' admirers was an Italian scientist named Galileo Galilei, born in 1564. Galileo was convinced that Copernicus' idea about the solar system was the right one, and that the Church was doing a great wrong by hiding the truth. But Galileo had no way to *prove* that what Copernicus said was true. He was in much the same position as the philosopher who tried to prove that the sun would rise the next day.



A model of the simple "optik tube" used by Galileo to make his observations of the heavens. Galileo eventually went blind through studying the sun with his primitive telescope.



Galileo Galilei, one of the greatest men of science, pioneered in the fields of mechanics and astronomy. He was among the first to observe the heavens with a telescope, and from his observations he proved the Copernican theory of the solar system.

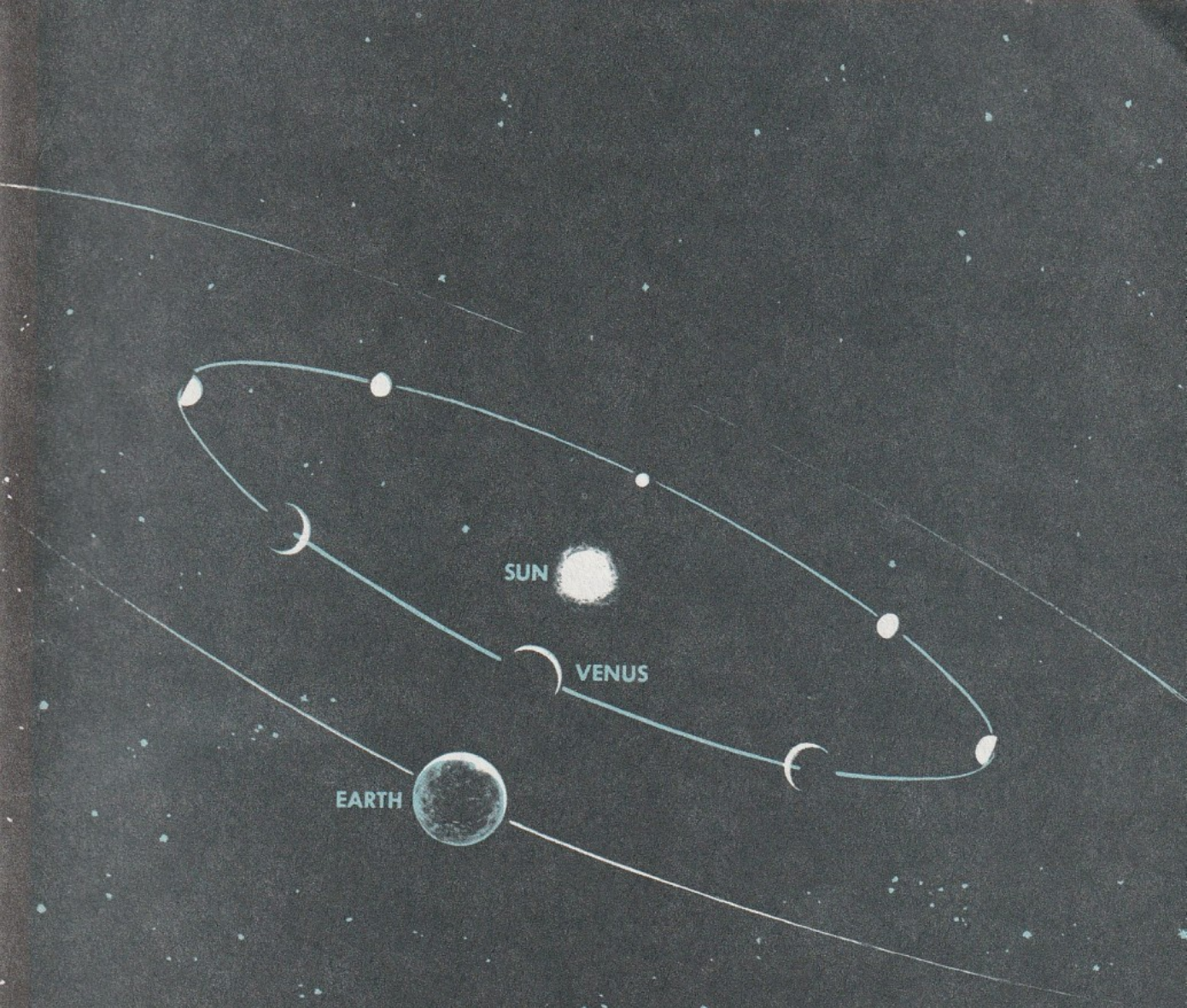
3. GALILEO

In 1608, however, Hans Lippershey, a Dutch eyeglass maker, happened to put two lenses together into a tube and invented the telescope. Galileo heard about the discovery and within a year was hard at work studying the planets through his own "optik tube".

As he watched the planets move across the sky he noticed something strange about Venus. It behaved much like the moon. At times it was "full", at other times it was a crescent, and at still other times it disappeared. At once Galileo realized what this meant. Here was *proof* that Copernicus was right—Venus was revolving about the sun.

Another discovery Galileo made was that the great planet Jupiter had four moons circling about it. When he first saw these moons of Jupiter, Galileo realized that he was gazing on a miniature model of our solar system.

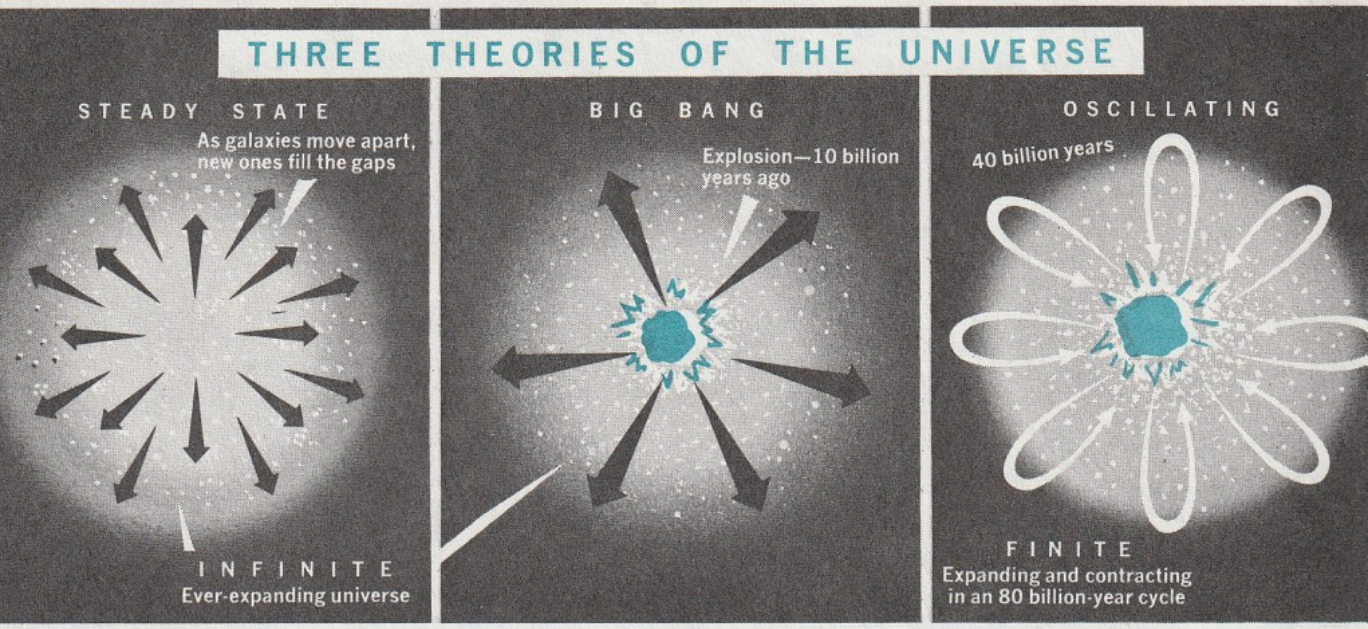
It was time, Galileo thought, that the world must be shown the proof of Copernicus' beliefs—in spite of what the Church might do. He wrote down his observations, which he published. When the Pope heard of this he issued a decree declaring that the earth, not the sun, was the center of the universe. Galileo continued to teach what he thought was the truth about the planets. Finally the Church summoned him to trial and publicly forced him to deny that the earth circles the sun. According to legend, when Galileo left the court he was heard to say: "In spite of what I have been forced to say here, the earth *does* circle the sun."



"MOON" PHASES OF VENUS AS FIRST SEEN BY GALILEO

The core of Galileo's proof that the sun was the center of the solar system lay in his observation that the planet Venus goes through phases just as the moon does. Galileo knew that the sun was the source of illumination of the planets.

Today Galileo stands as a bright beacon shining strongly through the darkness of superstition and hypocrisy. His concern for scientific truth and his careful examination of the heavens place him among the greatest scientific minds of all times. In his thinking he was worlds apart from the Egyptian astronomers, who knew that their knowledge of the heavens could be used for political power and prestige.



How Was the Universe Born?

ONE OF THE GREAT MYSTERIES of science is when and how the universe was born—a question that has baffled men since they first turned their eyes toward the heavens.

On a clear night thousands of stars can be seen by the naked eye. Through a small telescope millions more can be observed. Through the giant 200-inch telescope at the Hale Observatories atop Mount Palomar in southern California scientists can photograph countless billions of stars.

For more than three hundred years astronomers have been studying the universe with telescopes. They have measured the temperature of stars so far away that we can scarcely imagine their great distances.

Johannes Kepler, born in 1571, proposed the three laws of planetary motion by which the orbits of bodies in space are determined.

4. JOHANNES KEPLER

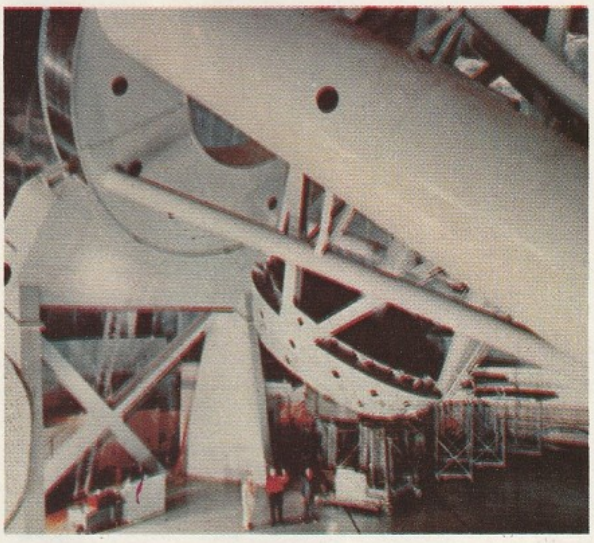
They have spent years studying stars which form mammoth organizations known as galaxies. And they have photographed vast clouds of gas and dust, called nebulae, which swim endlessly in the black ocean of space.

Now, as we peer farther and farther into the depths of space with radio astronomy we are able to detect and study an ever-increasing number of stars and star clusters. Just in the past decade, radio astronomers have made us aware of "flickering stars" that flare on and off a million times a second. Vibrating stars have been found shaking from nuclear explosions that rock their outer shells in a fixed time sequence. Eclipsing stars have been discovered that disappear as they whirl behind their neighbors at 100 miles a second. Scientists have found stars trillions of miles beyond the Milky Way whose outbursts of X rays pack radiating energy equal to 10 trillion stars the size of the sun. There are stars now known whose radio noise is a billion times that of our sun. Through radio astronomy we have "seen" stars cooling down and starting to die—and others that are heating up and being born.

Yet all of this work, which could fill the shelves of a library, still leaves one of the most tantalizing questions unanswered: How was the universe born?

Of the many exciting theories put forward to try to explain the nature of the universe, three are generally given the most serious attention.

Steady state theory. This suggests that there never was a beginning to the universe—that it always existed—nor will there ever be an end.



5. INSIDE MT. PALOMAR

This gives some idea of the gigantic size of the 200-inch telescope at the Hale Observatories atop Mount Palomar in California.

There are, this theory admits, local changes—stars are born, grow old and "die", and galaxies thin out by expansion of the universe, but new matter, in the form of hydrogen atoms, emerges as if by a miracle out of nothing, maintaining the average density of matter throughout space.

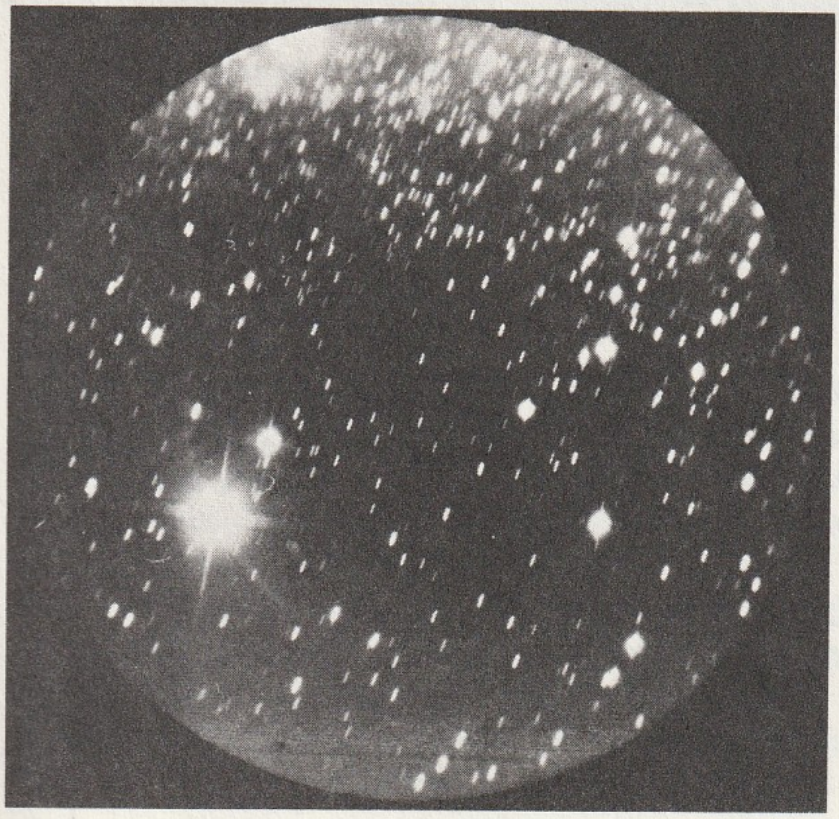
"Big bang" hypothesis. This theory holds that in the beginning all the matter of the universe was packed in one gigantic lump of extremely high density. The so-called creation of the universe was the explosion started at one moment some 10 billion or more years ago. Some "big bangers" feel that the fragments of the explosion—now our galaxies—will continue to move away from each other forever, like spots on the surface of an ever-expanding balloon. Others suggest that gravitational attraction will eventually overcome the outward motion and pull everything back together in a cataclysmic collision that will end the world.

Oscillating—or pulsating—universe. In this view, the "big bang" is a recurring event, and the universe periodically swells to some maximum size and minimum density, and then contracts to the size and density at which another big bang occurs, and so on endlessly. According to this view, we are now living in the expansion phase of the cycle. These cycles occur every 80 billion years. Since the last big bang occurred about 10 billion years ago, this theory holds, the universe has another 70 billion years before the galaxies crash together again.

Which of the three theories is regarded as superior to the others? If you asked that question a decade ago the answer probably would have been: "Take your choice."

But in the past ten years, the volume of knowledge about the universe —out to the reaches we can now study with the best radio telescopes and other means—has increased by thousands of times. Cosmology—as the study of the origin and structure of the universe is called—has made such great strides that a recent report by 100 scientists of the Astronomy Survey Committee of the National Academy of Sciences says the past decade could be likened to the era of discovery of Galileo and Newton 300 years ago. Says the Academy report: "While some puzzling phenomena remain, we have begun to see the outlines of a possible evolutionary history of the universe."

What has been revealed, the report says, is almost conclusive evidence that the universe was born about 12–13 billion years ago in the manner described by the "big bang" theory. Matter was flung out at tremendous speeds in all directions, say these astronomers, adding that the gas was so hot during the first instant of creation that hydrogen fused to helium. As this gas cooled, great lumps of it were drawn together to form the galaxies. Some galaxies—but not our own Milky Way—



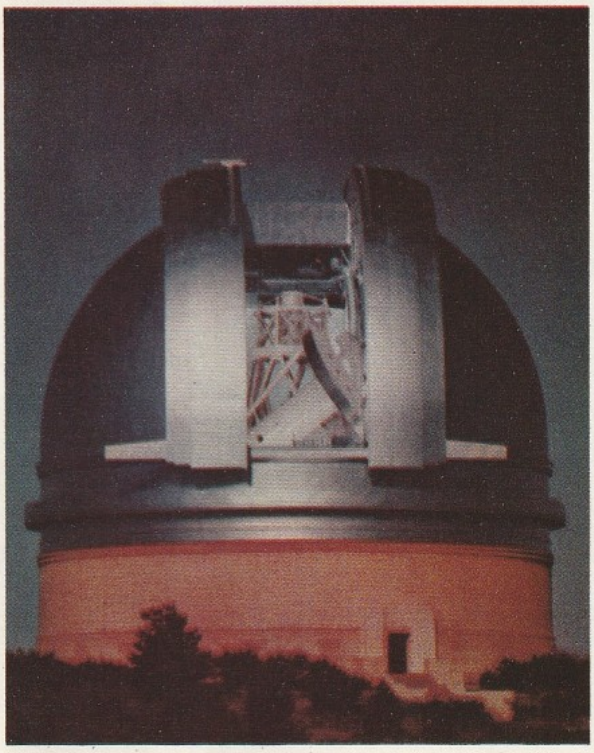
The Milky Way, as photographed from the moon by an Apollo 16 astronaut in 1972, using special far-ultraviolet light. The film recorded only hot, blue stars near center of galaxy. Stars are streaked as the thirty-minute exposure recorded the moon's rotation. The bright object at lower left is the planet Jupiter.

exploded, the remains of which are now being detected as quasars, about which we shall be hearing more later. As the galaxies took shape, the astronomers report, stars were born, including our own sun 5 billion years ago.

How Big Is the Universe?

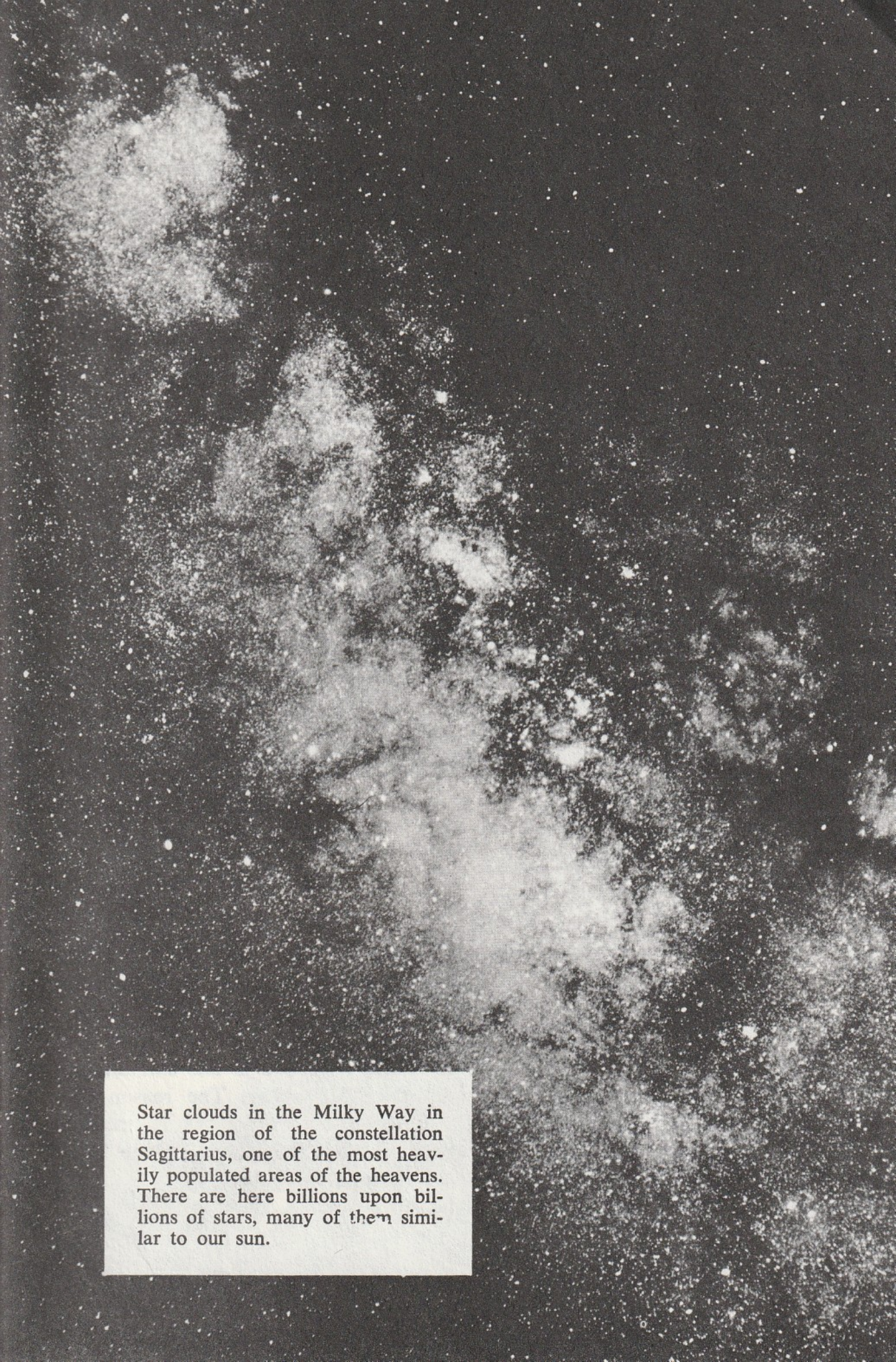
TRYING TO DETERMINE THE SIZE of the universe is like trying to find the very largest number in existence. As soon as an astronomer thinks he has counted all the galaxies, someone builds a more powerful telescope which can peer farther into space, where there are still more galaxies to be counted. But there *must* be an end, you are probably thinking. Well, if there is an end, or a limit to the size of the universe, no one has found it yet.

On any clear summer night when you look into the sky you can see a luminous, hazy band of stars parading across the heavens. Today we call this band the Milky Way. More than a hundred years ago when

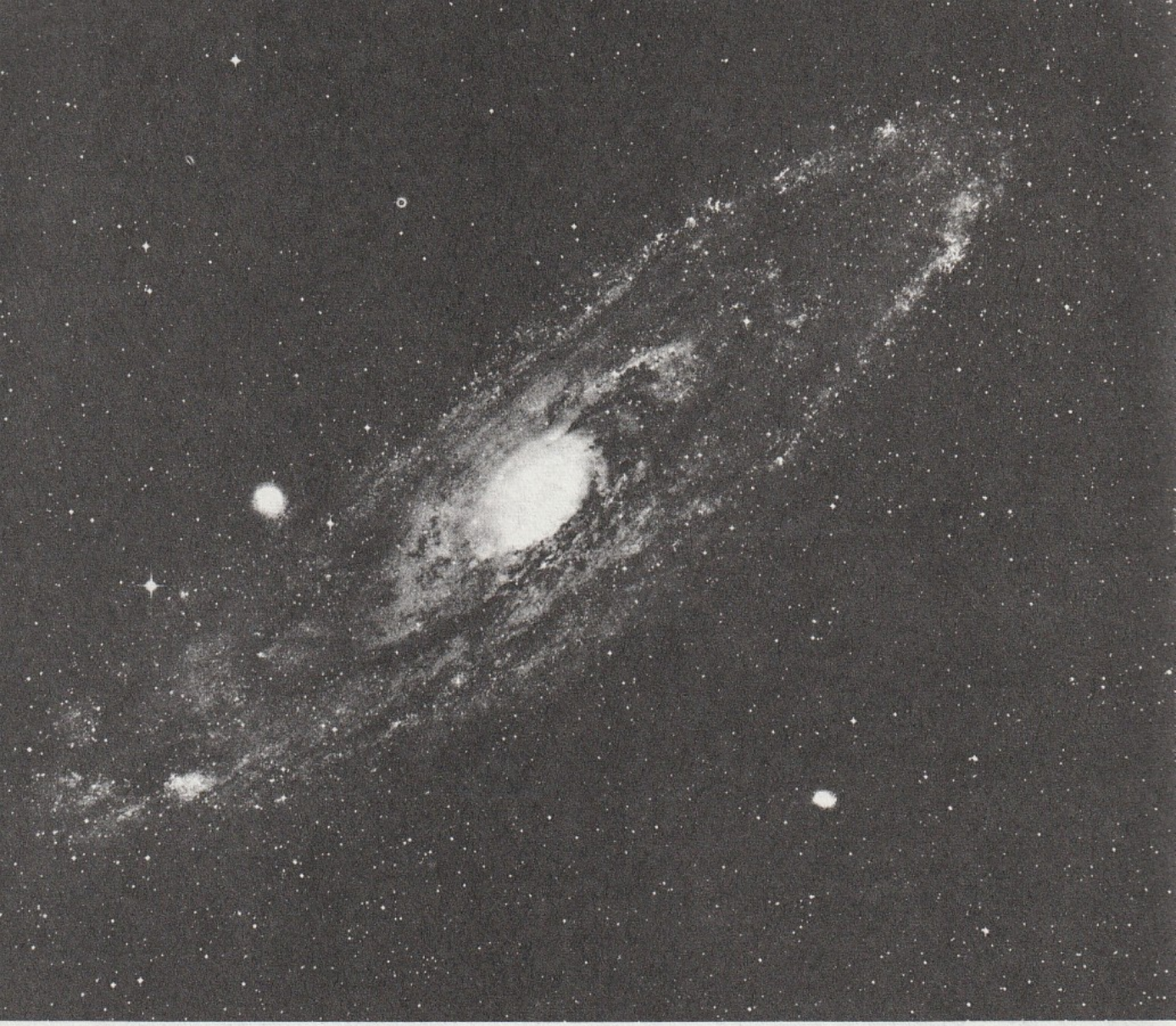


6. ATOP MOUNT PALOMAR

The 200-inch Hale Observatories telescope at Mount Palomar weighs more than 500 tons, yet is so perfectly balanced that a small, one-twelfth horsepower motor can move it easily.



Star clouds in the Milky Way in the region of the constellation Sagittarius, one of the most heavily populated areas of the heavens. There are here billions upon billions of stars, many of them similar to our sun.



The Great Nebula in Andromeda is an external galaxy, very similar to our own Milky Way galaxy. It is one of our closest galaxy neighbors but is nevertheless more than 2 million light-years away.

Sir William Herschel first studied the Milky Way, he decided that it must be in the shape of a large disc. And our sun, he thought, was somewhere near the center. Since Herschel's time we have learned many things about our galaxy. For example, we now know that the sun is not near the center. It is located near the outer edge and is one star among the 100 billion others that make up the Milky Way. The reason the Milky Way appears as a long belt stretching across the sky is because of the way we see it. From our position near the galactic plane (the center line), we are looking edgewise through the galaxy.

When astronomers talk about the Milky Way's stars and the great

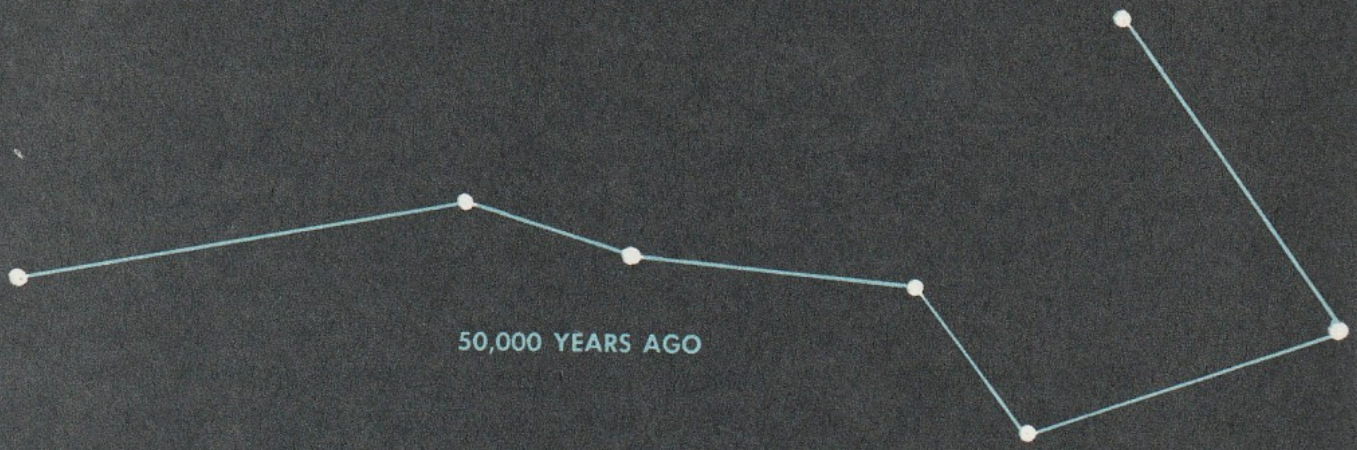
distances between them, they use a special system of numbers. Instead of using figures like this: 17,000,000,000,000,000 miles, to measure distances, they simplify matters by using *light-years*. For example the star Sirius is roughly nine *light-years* away from the earth. One light-year is the distance light travels in a year. Remembering that light travels 186,000 miles a *second,* this would mean that Sirius is 52 trillion miles away! Yet Sirius is considered to be a fairly close neighbor of ours. To express a light-year still another way, if the star Sirius should explode tonight, we would not see the blinding flash until nine years from tonight. It would take the flash that long to make the journey to our planet. Because the stars are so far away, when astronomers see changes in distant suns they are looking back into time, seeing things that happened long ago.

Applying our light-year yardstick to the Milky Way, we come up with some interesting figures. For example, the distance from one end of our galaxy to the other is 100,000 light-years. And the thickness at the center of our giant disc of stars is 10,000 light-years. Located near the rim of the Milky Way, our sun with its system of planets is about 30,000 light-years from the center of our galaxy.

Like other galaxies, the Milky Way has its thickest cluster of stars at the center of the disc. Toward the rim the stars begin to thin out; the distances between them become greater. If this is true, you might ask, why is it we are unable to see the bright center of the Milky Way? Astronomers found that between us and the bright center are many clouds of interstellar dust and gas hiding what would probably be the most exciting view in the entire galaxy.

In the early days of astonomy stargazers divided the heavenly bodies into two groups—the "fixed" stars and the "wanderers". The planets were called the wanderers because it was an easy matter to watch them change their positions from night to night. But the stars presented a different picture. To detect their position changes—different from their rising and setting motion—requires special instruments and many years of observation. They are so far away from us that they appear to stand still with respect to each other. For this reason the ancients called them "fixed" stars. Today we know that the stars are speeding through the heavens at about 40,000 miles an hour on the average. But we might ask, "If the stars move, then why do not the shapes of the constellations change?" Actually the constellations' shapes are changing, but so slowly that we do not notice the change. One hundred thousand years from now the

HOW THE BIG DIPPER CHANGES



50,000 YEARS AGO

AS IT APPEARS TODAY

50,000 YEARS FROM TODAY

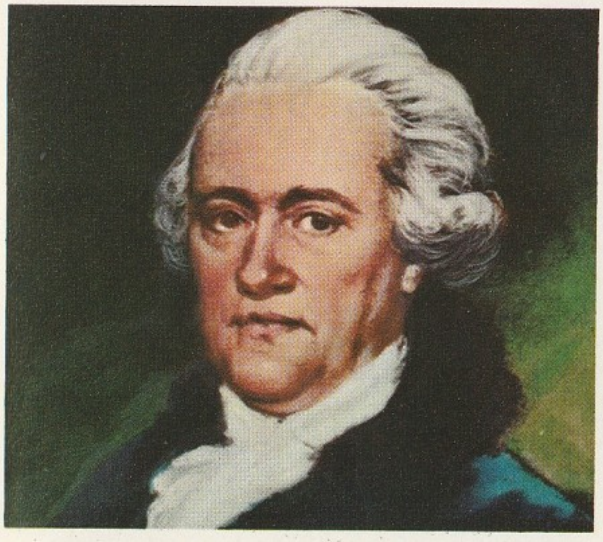
Big Dipper will have a completely different shape. People of the future will probably tax their brains trying to figure out why we ever chose the name "Big Dipper".

While the individual stars have motions of their own, they also move as a group. The Milky Way is forever spinning like a giant Fourth of July pinwheel, but its spin is much slower than that of a pinwheel. Astronomers say that in the last two billion years or so, our galaxy has made fewer than ten complete turns. But in spite of its "slowness" the stars on the rim of the galaxy are thought to be whipped around at hundreds of miles a second. Some astronomers have thought that this pinwheel motion is what has caused our galaxy to flatten out in the shape of a disc.

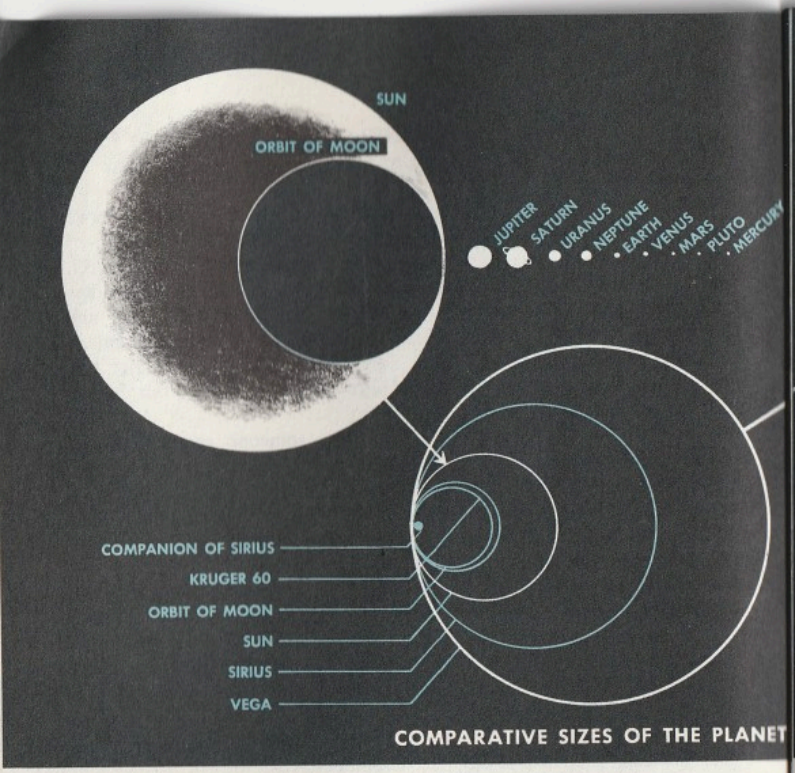
What does all this mean? The next time someone accuses you of moving too slowly you can tell him that you're really traveling several thousand miles an hour. Add to your own motion: (1) the speed of the earth as it spins like a top; (2) plus the earth's speed as it circles the sun; (3) plus the sun's speed as it wanders through space; (4) plus the sun's speed as it revolves around the nucleus or center of our galaxy; (5) plus the speed of the galaxy as it moves through space.

For many years astronomers thought of the vast collection of stars seen in the Milky Way as being the entire universe. Beyond the limits of our star system there was thought to be nothing, only the black

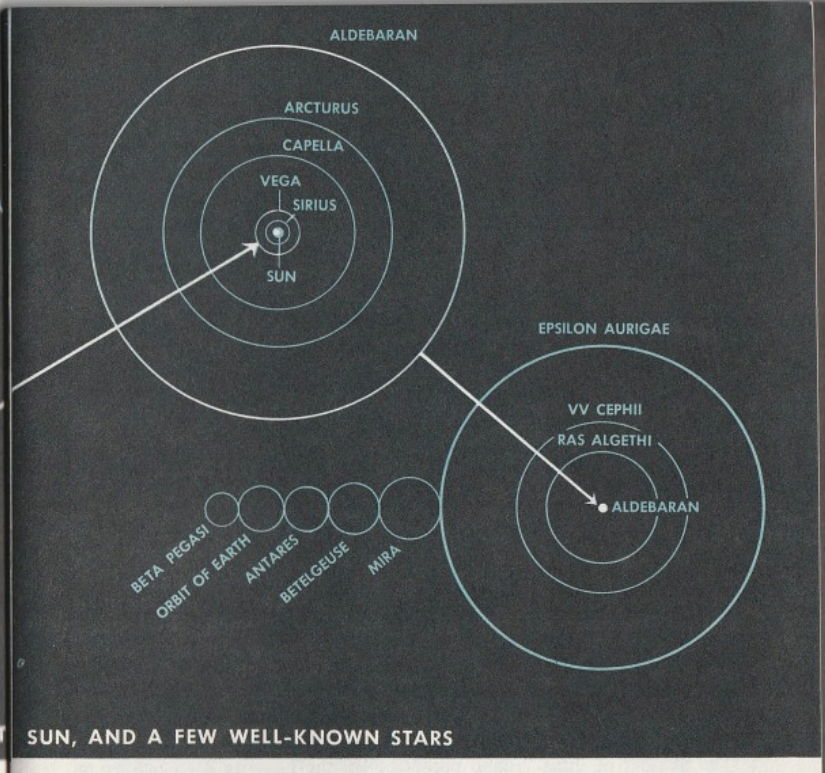
Sir William Herschel, born in 1738, could be called the first of the great observational astronomers because of his pioneer examinations of the heavens. He also made his own instruments.



7. SIR WILLIAM HERSCHEL



COMPARATIVE SIZES OF THE PLANET



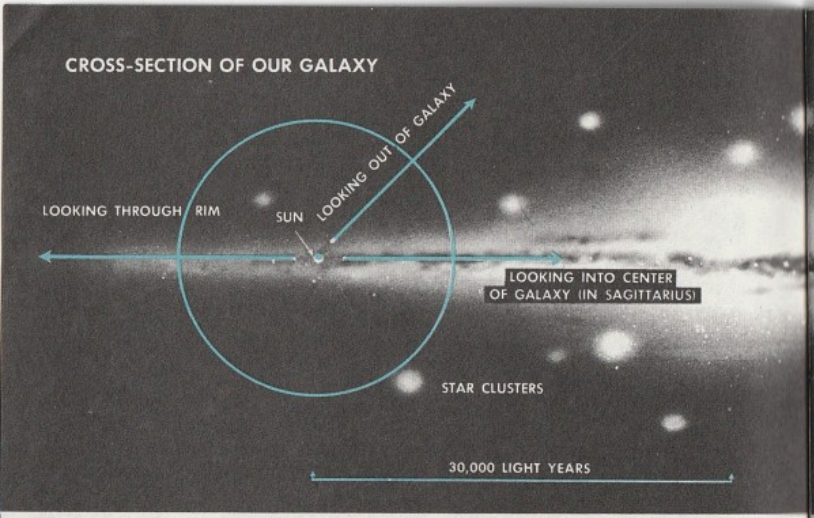
SUN, AND A FEW WELL-KNOWN STARS

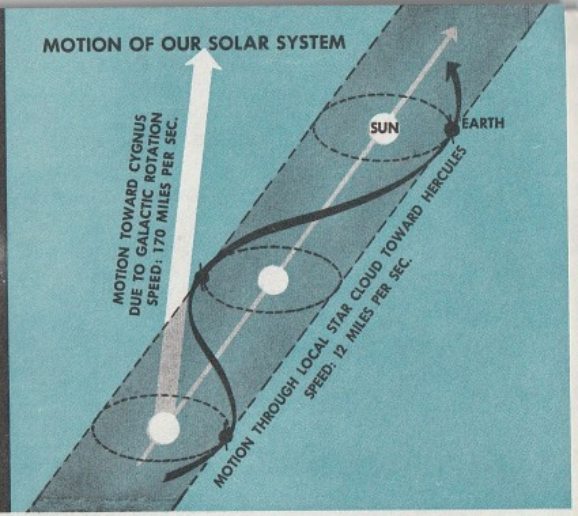
empty sea of outer space. If this were so, our problems of understanding the universe would be much simpler than they are. For many years Galileo and his followers looked through their telescopes in an attempt to understand the thousands of pinpoints of light dancing before their eyes. In some regions, the view became blurred by huge dark clouds in space.

One astronomer, a Frenchman named Messier, specialized in watching comets. In his search for comets he would frequently find his telescope pointed at misty patches of light in the sky. He had little interest in them but, like a good astronomer, he made a record of each one he saw, listing

all of them as "objects to avoid". In 1771 he published a booklet containing a total of forty-five of the light patches.

In 1773, when Sir William Herschel began his work in England, he suspected that Messier's misty clouds, or nebulae, might actually be giant clusters of stars. After years of study he drew two conclusions about them. One kind of nebula, he felt, most certainly was a series of giant star clusters. But the other kind, he said, was most likely made up of huge clouds of interstellar gas and dust. Both, he thought, were contained within the Milky Way. But as the years passed and Herschel studied the heavens more carefully, he began to wonder: Is there a possibility




MOTION OF OUR SOLAR SYSTEM
SUN
EARTH
MOTION TOWARD CYGNUS DUE TO GALACTIC ROTATION SPEED: 170 MILES PER SEC.
MOTION THROUGH LOCAL STAR CLOUD TOWARD HERCULES SPEED: 12 MILES PER SEC.

that these star clusters are not part of the Milky Way? Could they be trillions of trillions of miles out in space? And if they are, *does this mean that there is more than one "universe"?*

It was not until the 1920s that these questions were finally answered. Working with the 100-inch reflector at the Mount Wilson Observatory, astronomers showed that the Great Nebula in Andromeda and others like it are millions of light-years outside our galaxy.

The number of these "island universes" in the heavens is staggering to the imagination. A large telescope will bring into view more galaxies than the naked eye can see stars. In all, astronomers think that about a billion galaxies can be photographed through our largest telescopes! How many more lie beyond is anyone's guess.

Galaxies seem to group themselves into clusters which number from a few to several hundred. They were held together by gravitation, as our planets are held close to the sun. When we begin to talk about the great distances separating the galaxies, the numbers become so large that they are meaningless to most people. For example, the Great Nebula in Andromeda is one of our closest spiral galaxy neighbors. Yet it is 2.3 million light-years away.

By studying and photographing many of the galaxies, astronomers have discovered several different types. One scientist suggests that the

galaxies come in five different models. First are the *spherical* galaxies, which are shaped like globes with fuzzy edges. Next are the *elliptical* galaxies, then the *transitional* type. The fourth kind is the *closed spiral* galaxy. A slow-moving pinwheel will give you an idea of what this kind looks like. And the fifth kind is the *open spiral* galaxy. This one looks like a swiftly spinning pinwheel shooting long arms of fire. By arranging the galaxies into such groupings, some scientists think that it is possible to tell a galaxy's stage of development.

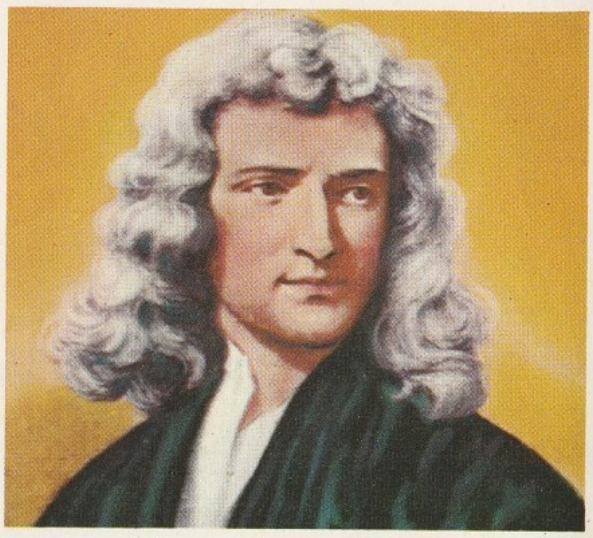
If you should spend several nights at a telescope studying the Milky Way and its neighbor galaxies, you would probably note several dark obscuring clouds that would spoil your view. These are the true nebulae —vast cosmic clouds of fine dust and gas. One of the most spectacular nebulae in the heavens is the one called the Horse-head, located in the constellation Orion.

Astronomers think that these mammoth clouds are the stuff out of which the stars are born. Over periods of millions of years these great clouds close in on themselves. As they contract they form individual globes of matter which become fiery-hot and begin spinning. As the heat becomes greater, the hydrogen in the globes changes to helium, a process that is similar to what happens in an H-bomb. Our own sun is one such "H-bomb", or star.

The Great Nebula in the constellation Orion, one of the most magnificent in our galaxy and one of the few that can be seen with the naked eye. Actually it is a great cloud of gas surrounding a group of hot blue stars. The whole Nebula appears slightly greenish in hue. It is twenty-six light-years in diameter, and its light takes about 1,600 years to reach us.

This famous globular cluster is known as Omega Centauri. It is visible to the naked eye.

Sir Isaac Newton, born in 1642, was one of the greatest men of science. His discovery of the laws of gravitation helped explain the physical nature of the universe.



8. SIR ISAAC NEWTON

Not all of the dust clouds in galaxies become stars, however. Some of the clouds simply drift through space, perhaps never closing in on themselves. The Horse-head Nebula is one such cloud. Another is the famous Ring Nebula, which in fact may once have been blown out by the star it surrounds. It looks like a giant smoke ring floating in space. Actually it is a huge spherical shell of dust and gas. Since it has a greater thickness around its edge, it appears to have the shape of a ring.

Red and Blue Giants

TO THE NAKED EYE the stars appear to be little more than flickering pinpoints of white light hanging in the black depths of endless space. Yet a close look, even with the naked eye, reveals them as jewels shining with every imaginable hue—faintly red, pink, yellow, violet, blue. The different hues of stars interest astronomers because they help determine a star's temperature and age.

Astronomers divide most of the stars into two large groups. In the first group are the stars found in the rings and arms of spiral galaxies, and in certain other galaxies. The brightest and largest stars in this group are called the blue-white giants, whose surfaces burn at temperatures up to 100,000° F. The blue-white giants are thought to be the youngest of all the giant stars.

9. A STELLAR CLOCK

Early clockmakers often made elaborate machines, such as the stellar, or star, clock shown here, to follow the movements of the sun, moon and planets.

On the center spread, bound into the book, is your FIND-A-STAR, with which you will be able to locate and name all the major constellations and some of the brighter and better known stars in your skies. Before putting together your FIND-A-STAR, read the illustrated directions carefully. With careful use, the FIND-A-STAR should give you many happy hours exploring the heavens and identifying well-known star patterns that have fascinated astronomers from very early times to the present.

FIND-A-STAR — A Guide to the Major Constellations in the Northern Heavens

DIRECTIONS FOR USE: Turn circular star chart so that month and approximate date are aligned with the hour of observation. Face North. Hold the FIND-A-STAR over your head so that the North pointer is *still pointing North*. The major constellations and many of the brighter stars can then be identified from the chart by direct comparison with the heavens. For best results choose a clear night without a moon.

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PRESS OUT CIRCULAR STAR CHART ALONG PERFORATED LINES

With a penknife, gently bend up staples binding book. Remove complete card from book. Bend staples back into place.

Directions for assembling this FIND-A-STAR are on the other side. Trim off this section of card at the scored lines and discard.

1

With a penknife, gently pry up the staples that bind the book together; remove the whole card; carefully bend back the staples into their original position. Flatten card to remove crease.

2

Carefully press out the circular star chart in the center of the card as shown here, making sure that the chart is not damaged or bent.

3

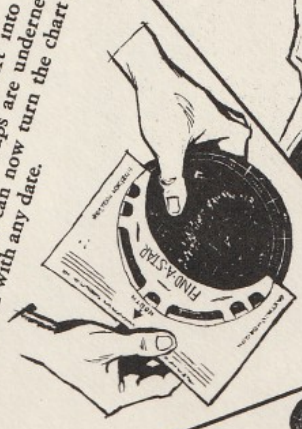
Separate the top half of the card from the bottom half. Discard the bottom half – you won't be needing this piece any more.

4

Press out the piece of card in the center of the "half moon"; bend down just a little all the short and long flaps marked PRESS.

5

Carefully insert the circular star chart into the headboard, making sure the flaps are underneath the circular chart. You can now turn the chart to line up any hour with any date.



Science Bulletin
Prepared by SCIENCE SERVICE

CLOCK PARADOX

According to the theory of special relativity a clock that is moving will record less time than one that is standing still. This leads to the famous clock paradox: that a clock which makes a round trip will be slow with respect to one that stays put. An astronaut on an interstellar flight would come back to earth perceptibly younger than his twin who had stayed home.

People have refused to believe it could happen. J. C. Hafele of Washington University and Richard E. Keating of the Naval Observatory report that it does.

The test involved cesium-beam clocks flown around the world, one eastward, one westward. Compared to clocks on the ground (which move with the earth's rotation) the eastward flight should lose about forty nanoseconds (one nanosecond is one-billionth of a second), the westward should gain about 275. The results agree with the prediction.

Hafele and Keating conclude, "There seems to be little basis for further arguments about whether clocks will indicate the same time after a round trip, for we find that they do not."

PREDICTING PROPERTIES OF PLANETS AND SATELLITES

John S. Lewis of the Massachusetts Institute of Technology has been exploring the chemical process by

which planets formed out of gas of the same composition as that of the sun. Using a model developed by A. G. W. Cameron for the temperatures of the solar dust right after the collapse of the nebula, he has developed computational techniques for predicting the composition of the planets. The model has already predicted the correct densities for the inner planets. The only thing that varies from planet to planet is the temperature at formation. For the model he assumes the planets were formed at the same distances from the sun as they are now.

In his model, Mercury should have formed at high temperatures and should be rich in iron. The silicates would not have completely condensed from the gas. Venus would retain everything except the sulfur. The earth would have a sulfur-rich iron core. Potassium would also end up in the core. The model for the core of Mars agrees with a recent model by Don Anderson of the California Institute of Technology for a Martian core devoid of metallic iron. It would be a small iron-sulfide core with a dense mantle because of the higher iron oxide content.

He has also applied the model to outer-planet satellites. The satellites of Jupiter would have formed at temperatures of 130 degrees below zero C. Rocks and ice would have condensed out together to form the planet.

A NEW TRANSIENT X-RAY SOURCE

A flaring X-ray source, a kind of X-ray nova, has been found in the constellation Lupus by the X-ray observing satellite Uhuru.

Optical novas, in which a star jumps from relative obscurity to sudden brightness and then dies down, are a well-known phenomenon. They are explained by supposing that a star explosively sheds some of its outer layers of gas. X-ray novas seem to be different. This one did not cool down in the way an expanding shell of gas should. Furthermore no visible light could be seen from

it. If it is the same basic phenomenon as an ordinary nova, this means it must be more than 30,000 light years away because the visible light from a nova should be seen up to that distance.

But then the observed strength of its X-ray emission is hard to explain. Possibly it is a white dwarf star, suggest the discoverers, T. A. Matilsky, Riccardo Giacconi, Herbert Gursky, E. M. Kellogg and H. D. Tannanbaum of American Science and Engineering.

PLANET FORMATION

Most theories about the origin of the solar system include the formation of planets through accretion —series of collisions between solid grains (condensed from gas) causing them to become attached.

Compositions of the planets indicate that most of the particles accreting were probably silicates. John F. Kerridge of the University of California at Los Angeles and James F. Vedder of NASA's Ames Research Center report the results of an experiment that sets a limit on the possible speeds at which the accretion of the particles can occur.

They conclude that accretion of silicate flakes would not have occurred during impacts in the velocity ranges from 1.5 to 9.5 kilometers per second, which they studied using artificially accelerated flakes. Accretion probably occurred at speeds slower than 1.5 kilometers per second.

SOLAR WIND TURN-AROUND

Scientists have theorized that magnetic storms, the auroras and disturbances in radio transmissions, are caused by charged particles from the solar wind —electrons and protons that stream into space from the sun. But the earth's magnetic field forms a protective shield around the earth causing the solar wind to flow past, so how enough solar particles could get inside

the barrier to cause the observed disturbances has not been clear.

Anand Prakash of the Massachusetts Institute of Technology may have an answer. He has discovered the occurrence of earthward-flowing solar wind protons in the far magnetosphere. As the solar wind flows past the earth, it elongates the earth's magnetic field on the night side into a long tail that trails off in the direction away from the sun. At some point (now known to be past the moon-distance) the fields merge into a neutral line. It is at this neutral line, says Prakash, that solar wind particles are entering the earth's magnetic field. There they double back, following magnetic lines of force to the earth's surface and particularly to the poles.

His evidence comes from Explorer 35—a moon satellite. As the moon passed through the earth's magnetic tail, the satellite detected protons flowing the "wrong way" —back toward the earth and the sun. The protons had energies enough to cause magnetic storms and influence the northern lights and radio transmissions.

An artist's conception of two colliding galaxies. The distance between stars in a galaxy is so great that rarely, if ever, do stars actually collide; the two galaxies just pass through each other.

In the second group are the stars found in the crowded centers of galaxies. The brightest and largest in this group are the red giants. They are in the later stages of life and are relatively cool. Their surfaces burn at temperatures up to 6,000° F. A thick grouping of these stars glows with a light red tint.

If you were to chart the life of a star you would come up with a picture something like this: Early in the star's life it burns evenly without change. After it has used fifteen per cent of its fuel it begins to be wasteful. In a short time it burns the remaining eighty-five per cent.

A spiral galaxy in the constellation Virgo seen on edge. It is often referred to as the Sombrero Nebula because of its resemblance to the wide Mexican hat. This galaxy cannot be seen with the naked eye.

Soon it swells up, and as it expands, it cools, growing fifty to 100 times its normal size. When it reaches this stage the star earns the name "red giant," or supergiant. Astronomers are not sure what happens next. Some think that in its dying stages the star may simply collapse suddenly and end its life as a small, intensely bright star, called a white dwarf.

How long does the average star live? Some for as long as 50 billion years. If we take our own sun as an average star, it may still be in its youth—a mere 5 billion years old.

In many ways the death of a star can be much more exciting than its rather dull and monotonous life. Stars can die in either of two ways. They may simply burn themselves out and shrink into white dwarfs, or they may explode as a nova.

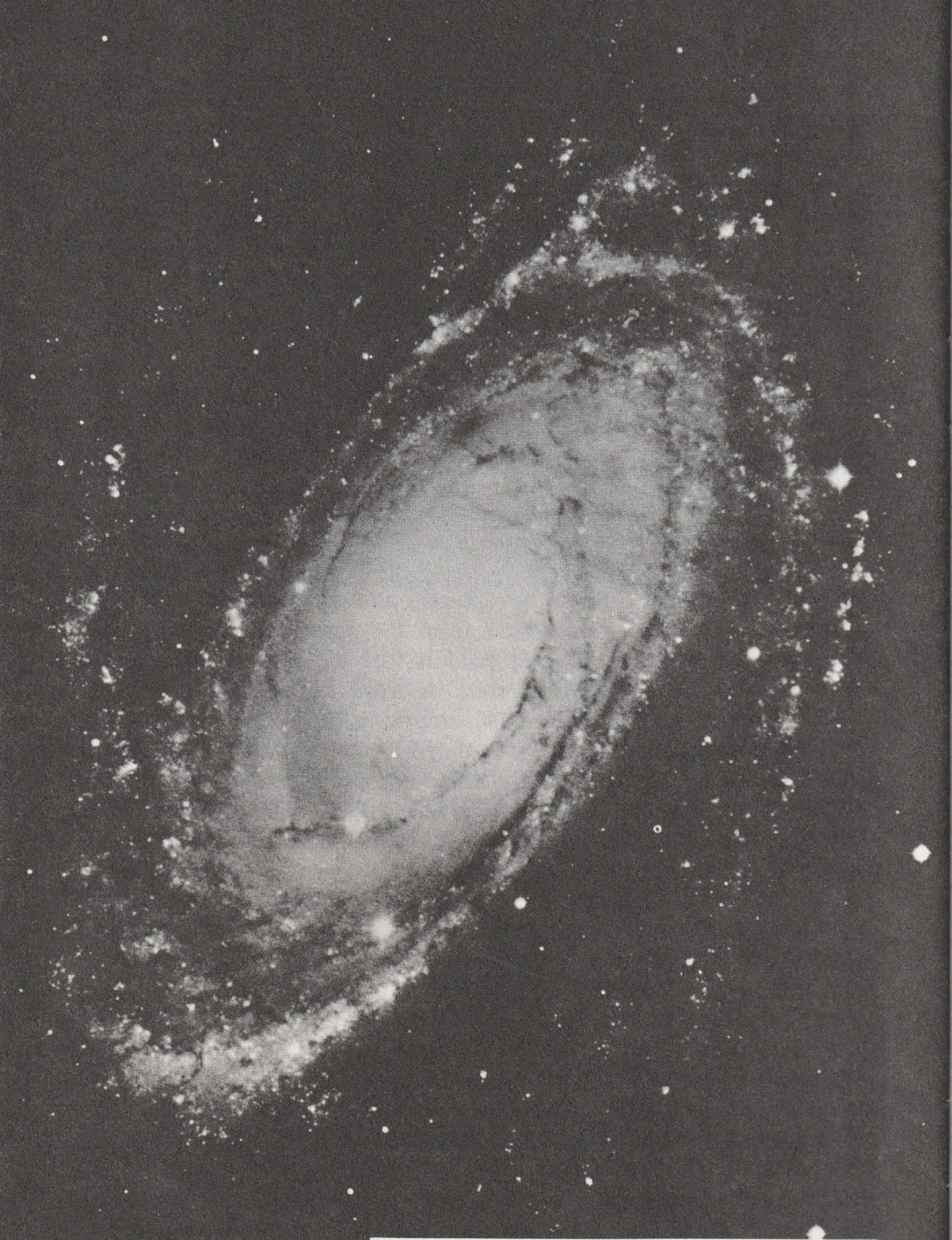
Nova and Supernova

IN THE YEAR 1054 Chinese astronomers saw and recorded something that terrified them. A certain star in the constellation Taurus suddenly grew brighter and brighter until it was the most brilliant object in the heavens, remaining visible even in broad daylight.

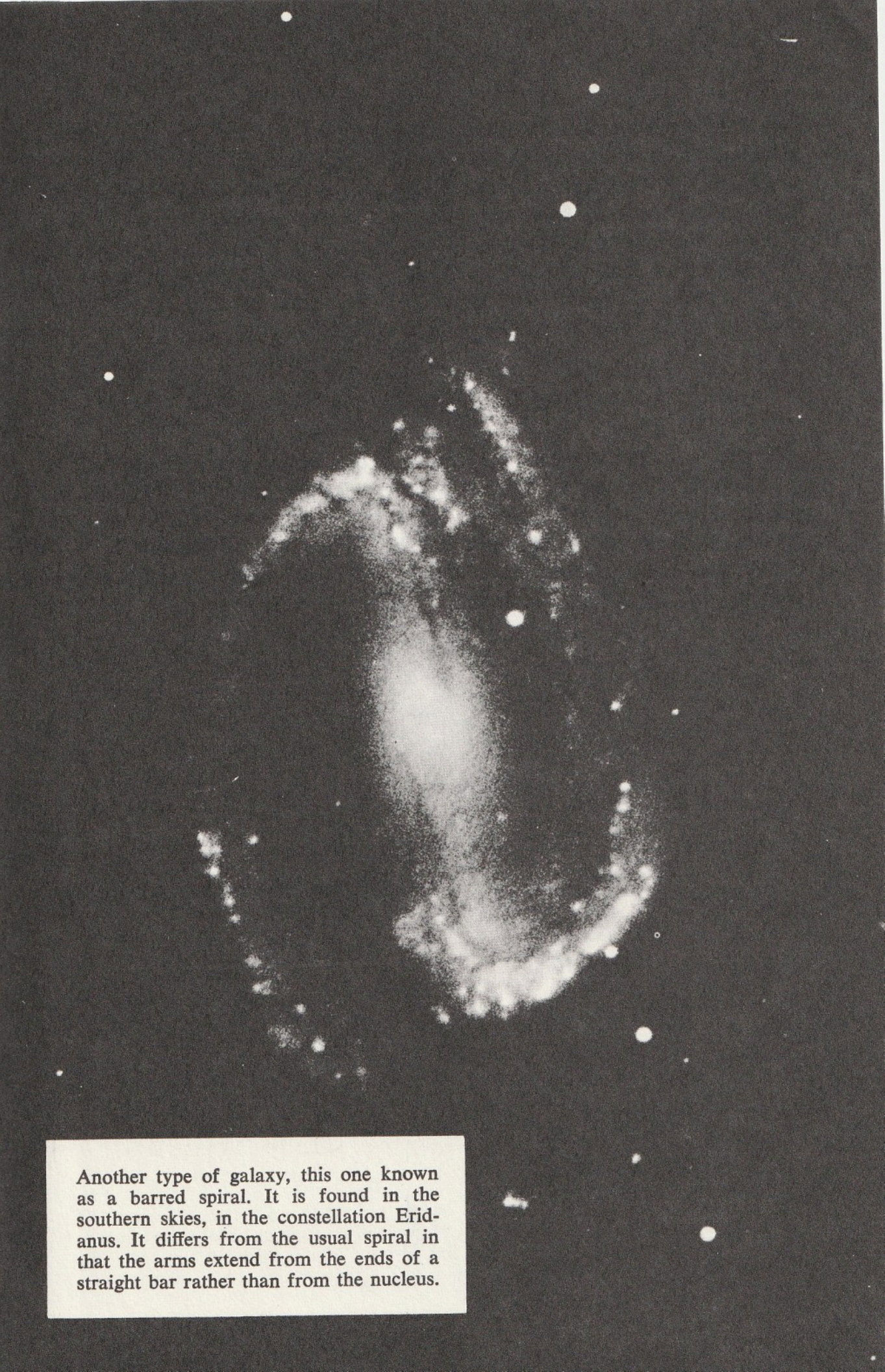
What the Chinese saw was a supernova, nature's most catastrophic event—a rare star that burns with the brilliance of 100 million times more luminosity than the sun, releasing the equivalent of 200 trillion trillions of the biggest hydrogen bombs. In all recorded history, less than 200 supernovas have ever been observed. When a nova is in the making, it suddenly begins to brighten until it may be visible to the naked eye where it never appeared to shine before. It may remain bright for several years. Then it will slowly dim, returning to its normal stage.

The supernovas are usually even more dramatic. They seem to be normal stars that suddenly explode and become as bright as a whole galaxy. Supernovas do not return to their normal state. Their own gigantic size proves their downfall. Why?

Scientists calculate that a star whose mass is greater than 1.44 times the sun's mass does not follow normal evolution. Over a few million years, burning hydrogen on the outer layers of such a star produces more and more helium at its core. The interior of the doomed star shrinks rapidly, while the density of its core increases. As the star gets hotter, the helium is converted into heavier elements—iron and gold are two—which crowd the lighter elements outward. Now the shrinkage really accelerates, heating the interior to about 5 billion degrees, suddenly converting the iron



One of the big spiral galaxies to be found in Ursa Major, the constellation that also contains the Big Dipper. The galaxy appears to spin and is held together by gravitational force.



Another type of galaxy, this one known as a barred spiral. It is found in the southern skies, in the constellation Eridanus. It differs from the usual spiral in that the arms extend from the ends of a straight bar rather than from the nucleus.

and gold back to helium. The tremendous energy for this conversion comes from gravitational shrinkage. When the energy demand becomes too great, the star rapidly collapses inwards, producing fantastic densities. Rebounding instantly from the collapse, the star explodes.

Some of the supernova's exploding mass enters the earth's atmosphere as cosmic rays. But a second wave of radiation and burning gases causes the supernova to shine with splendor for weeks or months or years until the star's remains gradually fade altogether.

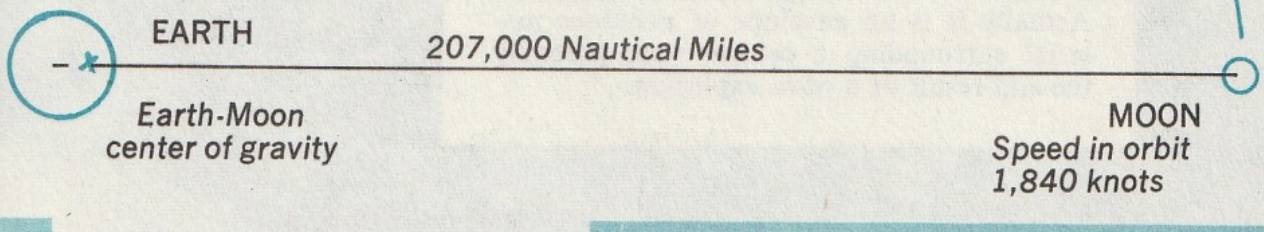
Double Stars In the Sky

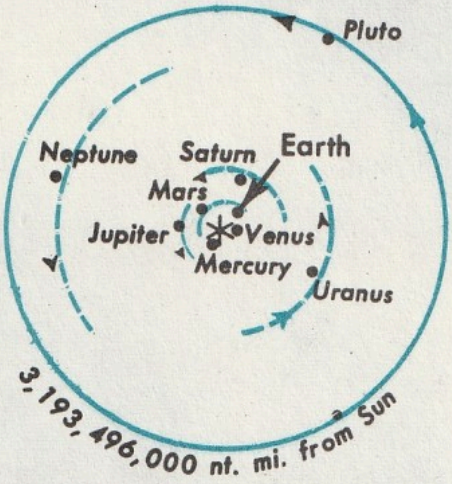
IN SIZE AND BRIGHTNESS our sun is a typical, or average star. More than three-fourths of the stars in our galaxy appear to belong to partner systems, or are members of a family of stars. Sometimes star families have hundreds of members. Yet many of the families do not exceed two, three, or four stars. Among the most interesting stars having companions are the double stars.

10. THE SCHMIDT TELESCOPE

The forty-eight-inch Schmidt telescope (camera) cannot be "looked through" in the sense that most telescopes can. It is used only to photograph the heavens. The man looking through the small telescope at right is guiding the camera.

Relative Locations in Space

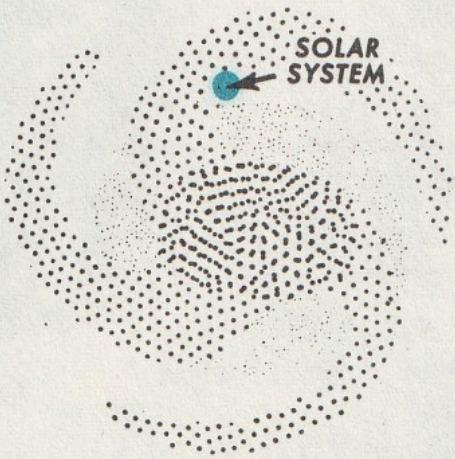




(1) THE EARTH AND MOON

(2) SOLAR SYSTEM —

Sun moving in space at approximately 420,000 knots. Distance from Sun to Earth about 8 "light minutes." Earth moving around Sun at 58,000 knots.

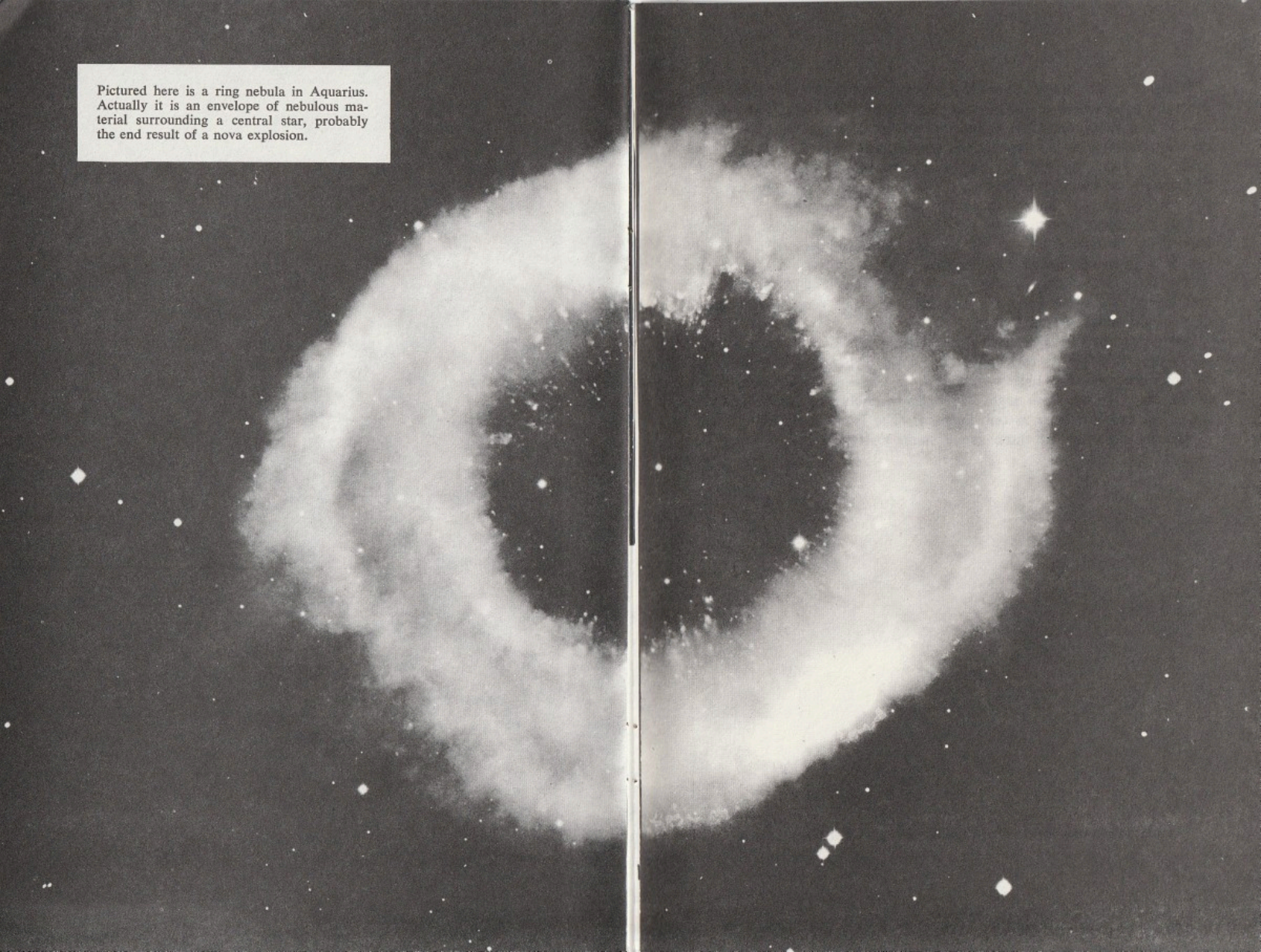


(3) OUR GALAXY —
(The Milky Way System)

80,000 light years in diameter. Sun is approximately 26,000 light years from center.

(4) THE UNIVERSE —

Observable distance from our galaxy in any direction about 8 billion light years.

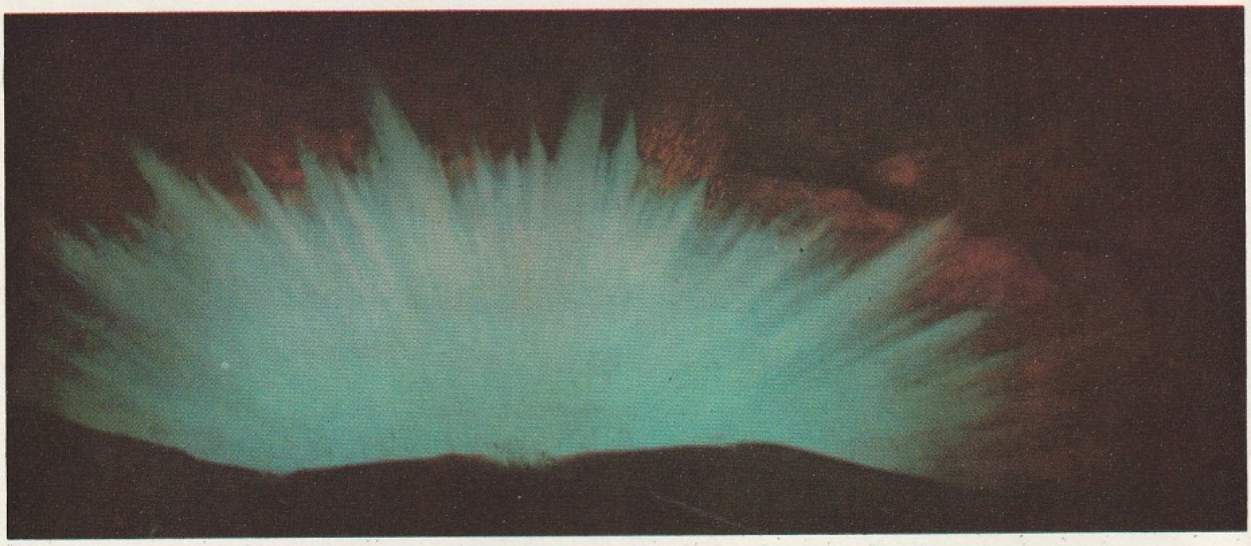


Pictured here is a ring nebula in Aquarius. Actually it is an envelope of nebulous material surrounding a central star, probably the end result of a nova explosion.

When two stars are situated close together in the sky and circle each other they are called a double star. Sometimes they circle one another rapidly and shoot out long, colorful streamers of gas. One of the most exciting displays of this type is the double star known as Beta Lyrae, made up of a large blue star and a smaller yellow one. They are surrounded by a spectacular display of luminous red gas. Beta Lyrae is the only double star known to put on such a colorful show.

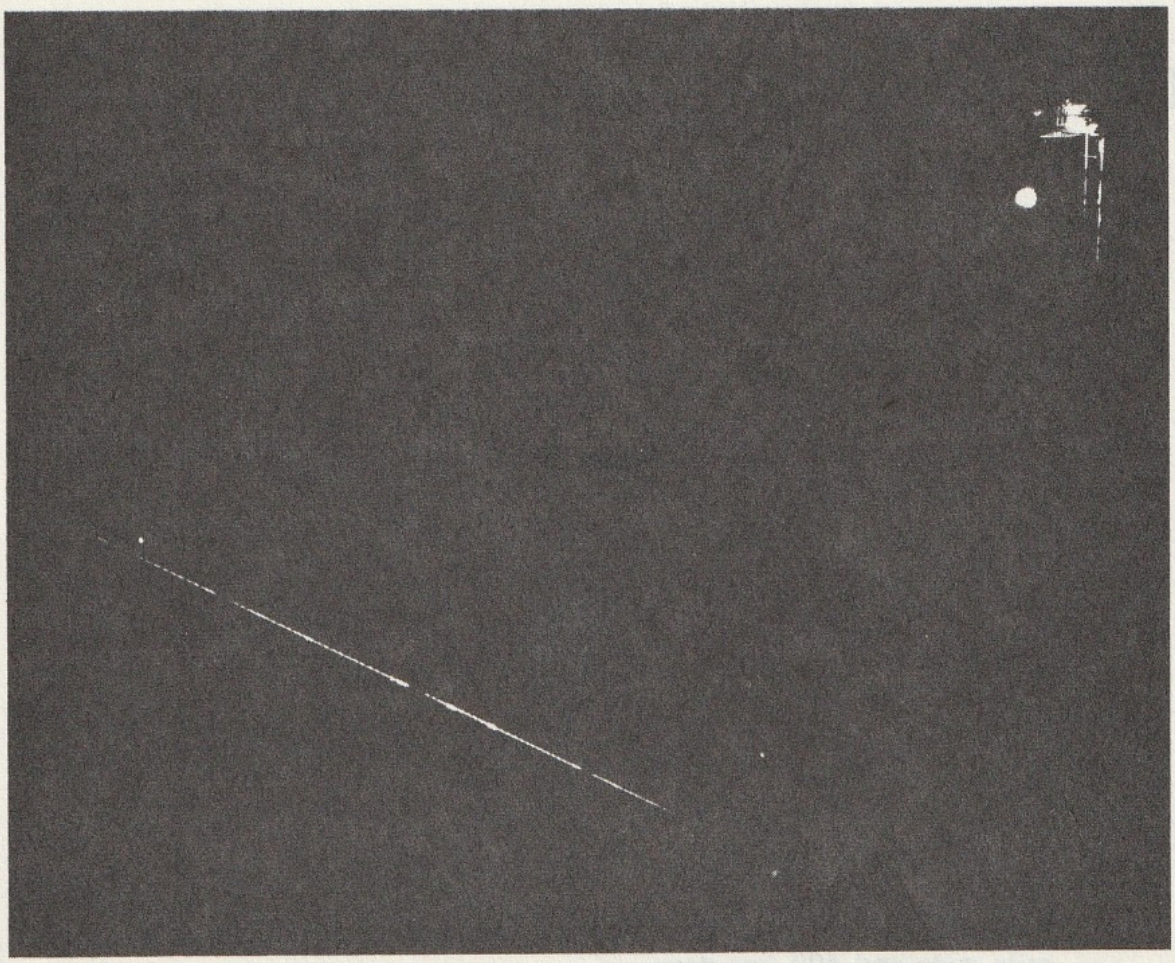
The first small family of stars ever to be seen was Mizar, which is located in the handle of the Big Dipper. Two members of this family can be seen by the naked eye. Another double star system is made up of the blue giant Sirius, known as the Dog Star, and a white dwarf companion called the Pup. The smaller star is so dense that a speck of it would weigh untold tons.

The prizewinner for size of all the double stars is Epsilon Aurigae. One of its stars is a yellow supergiant 250 times bigger than our sun. But its companion is even bigger—3,000 times the size of the sun. Many of the stars we see each night are actually double or triple stars, yet the naked eyes see them as only one star. The North Star, for example, is actually made up of three single stars. Castor is made up of six.



14. A METEOR CRASHES TO EARTH

An artist's conception of what happens when a meteor hits the earth.



A rare photo of a meteoroid trace. Six days after it was made, a 21.6-pound meteorite was found near Lost City, Oklahoma. The initial mass of the meteor in orbit was about one ton. It entered the earth's atomsphere at 32,000 miles an hour.

Meteors: Outer-space Monsters

THE TIME IS MORNING, 30 June, 1908. The place is northern Siberia, swampy and hilly wastelands stretching across thousands of miles. At the time of our drama most of the inhabitants of this area were wild animals. There were few human beings. Suddenly there appeared in the sky an object which seemed to be about half the size of the moon. At thousands of miles an hour it was plunging toward the earth. As it sped closer it set up a deafening roar—then with a terrifying explosion it smashed into the marshy ground.

Had this monster from outer space landed on New York, London, or Paris, it would have blasted the city into total ruin. Possibly not a single

13. METEOR CRATER IN ARIZONA

The great meteor crater near Flagstaff, Arizona, is four-fifths of a mile wide and 600 feet deep.

person would have survived. Even the H-bomb, man's most destructive weapon, would have had to bow to the great Siberian meteorite.

In the history of mankind only a few really large meteorites are thought to have crashed into our planet, and records of them have long since been lost. In North America, however, scientists have found two mammoth meteor scars. One of the giant pits is in Arizona, and measures about 600 feet deep and four-fifths of a mile wide. An even larger one is located in northern Quebec, Canada.

When a meteor survives the difficult trip through our atmosphere and manages to strike the ground, it is known as a meteorite. Most of the meteorites found so far can be divided into two groups—those made of stone, and those made of metal, part nickel and part iron. Of all the meteorites that have been examined, none is made of material that cannot be found on our own planet. This destroys the theory that some meteors might have "secret" and "mysterious" properties.

For many years people referred to meteorites as "shooting stars". The ancients may well have thought of them as stars that somehow lost their way and came tumbling down to earth. Although meteors are still called "shooting stars", we know that they are no more than chunks of stone and metal.

How Vast Is the Universe?

From the earth to the moon: roughly a quarter of a million miles.
Light takes 1⅓ seconds to travel this distance, traveling at 186,000 miles a second.

From the earth to the sun: 93 million miles.
Light takes 8 minutes to travel this distance.

From the sun to Pluto, the outermost planet of our solar system: 3.7 billion miles.
Light takes 5½ hours to travel this distance.

From the sun to Proxima Centauri, the star closest to our solar system: 25 trillion miles.
Light takes 4½ years to travel this distance.

From the sun to the center of our galaxy: 26 thousand light-years.
Light takes 26,080 years to travel this distance.

From the center of our galaxy to the center of the galaxy containing the great nebula Andromeda: 2.3 million light-years.
Light takes 2,262,000 years to travel this distance.

To the most remote galaxy yet photographed: 2,000 million light-years.
Light takes 2,000 million years to travel this distance.

To the most remote quasar yet observed: 12,000 billion light-years.
Light takes 12,000 billion years to travel this distance.

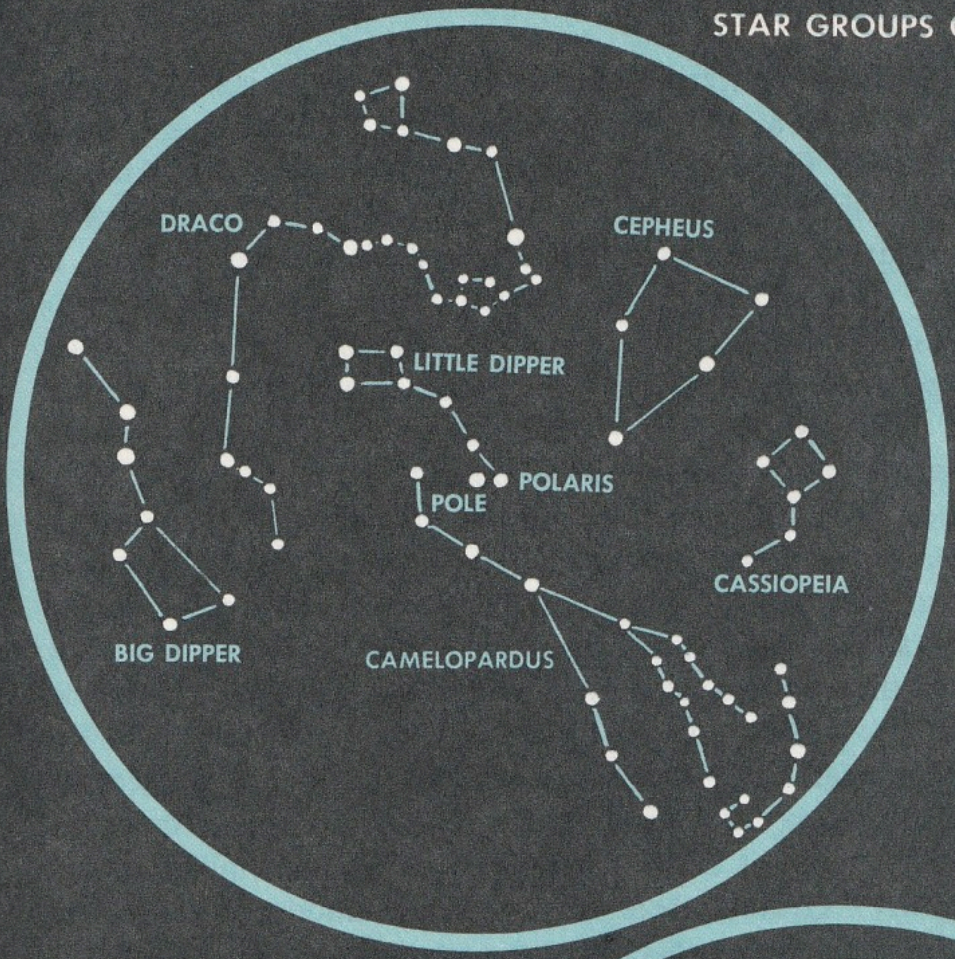
Comets: the "Celestial Snowballs"

IN MAY, 1910, millions of people sleepily climbed out of their beds in the early morning to watch one of the most spectacular of all heavenly displays—Halley's comet. When it was seen, many ignorant watchers were terrified. Like the ancients, they thought that some disaster was in the making for man and his world. What they saw was a large luminous globe which appeared to be the size of a star. Behind it a long shining tail stretched across the heavens for 90 million miles.

12. THE TOWER TELESCOPE

This instrument is used to study and take pictures of the sun. Underneath the 150-foot tower is a seventy-five-foot pit, which increases the focal length of the apparatus and thus increases the size of the solar image.

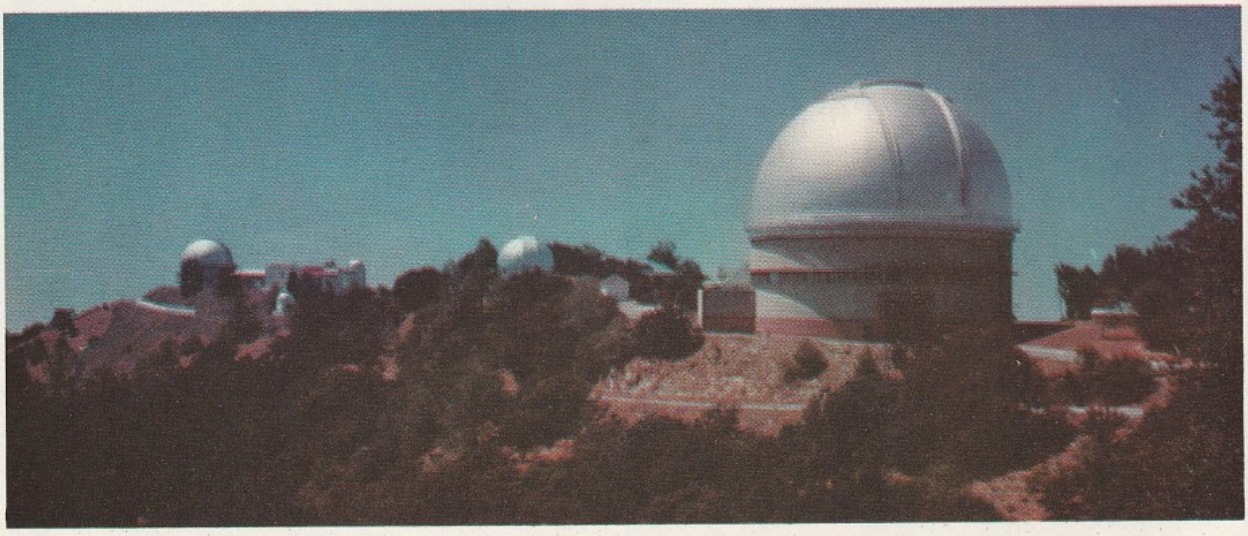
STAR GROUPS OF THE NORTH POLE



STAR GROUPS OF THE SOUTH POLE

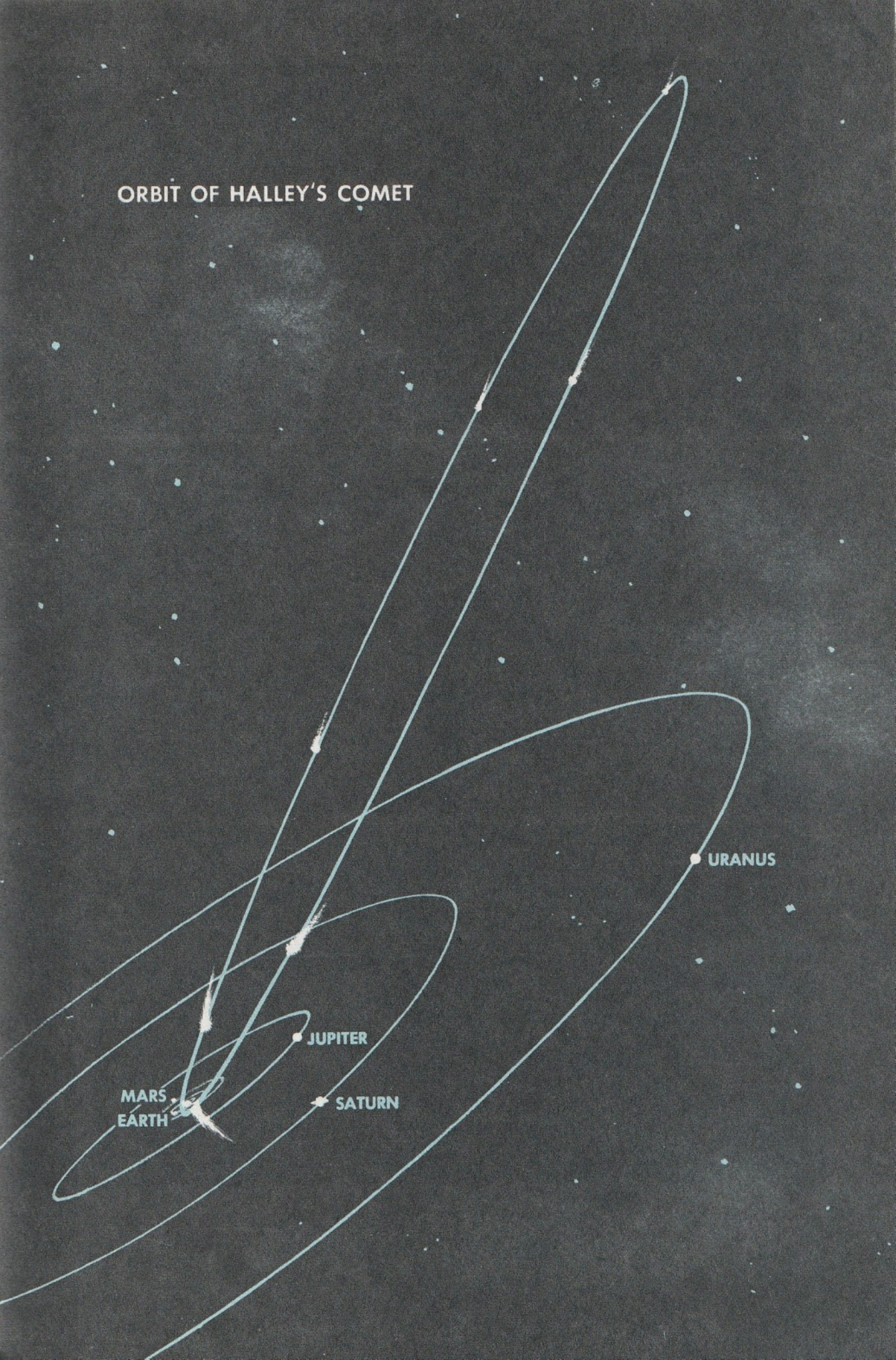
Had the people who were terrified known what a comet is, they probably would have laughed at their fear. Comets, as we now know from Kohoutek (pronounced Coe-HOE-tek) which swept across the skies in January, 1974, are little more than "celestial snowballs"—dirty ones at that. Their relatively small nucleus, whose diameter varies from a mile to twenty-five miles, is composed of dust, frozen gases and water—that is, ice and ice water and the so-called disassociated constituents of water, hydrogen and hydroxyl. At one time scientists thought that the comets were "flying sand banks." Now we know that water is more abundant in comets than any other chemical compound.

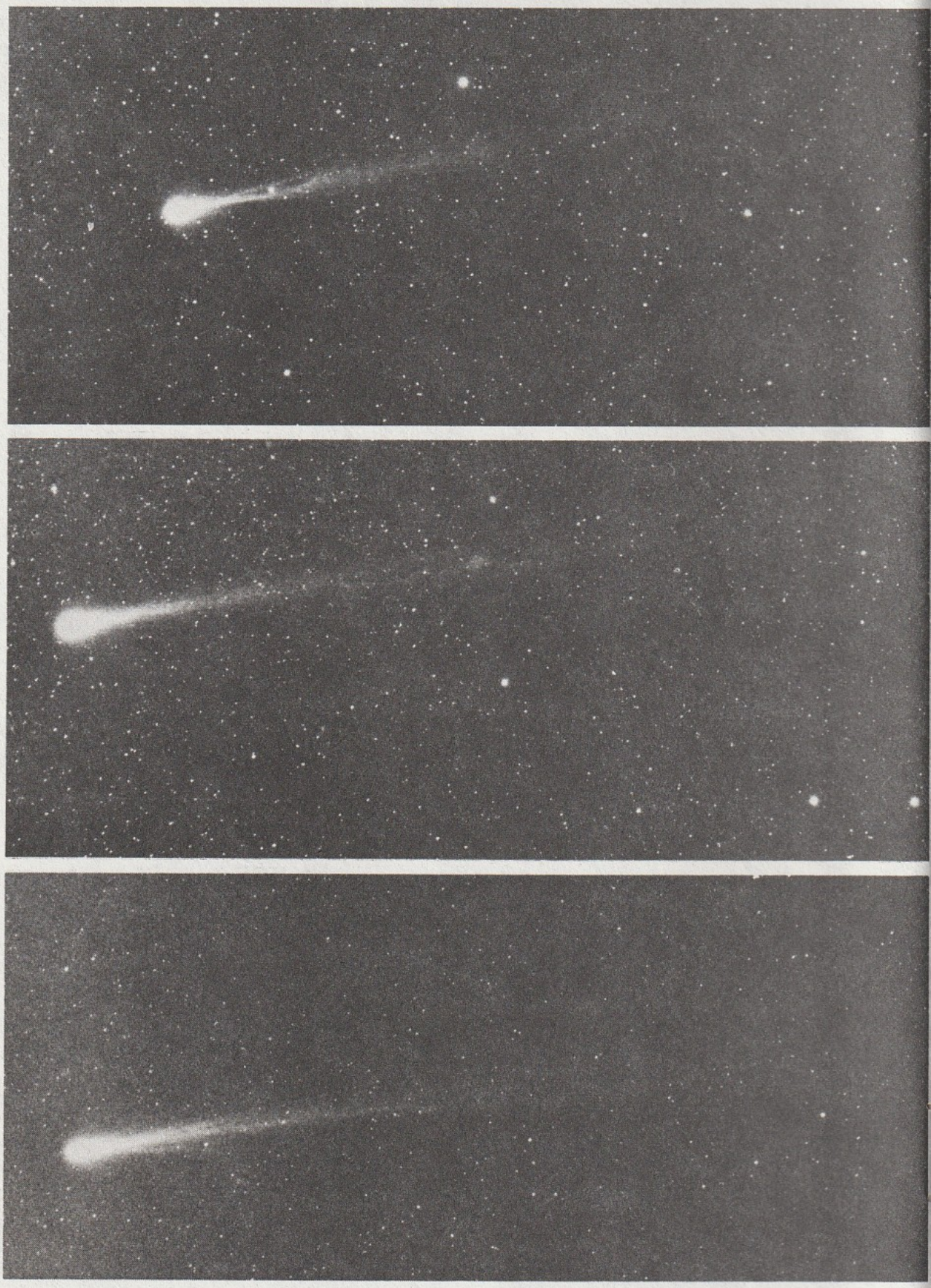
As a matter of fact, the detection of water vapor in Kohoutek's tail tends to offer further confirmation of the snowball theory. Actually Kohoutek had two tails, one of which stretched millions of miles across space. The main tail—of dust and ionized gas—was blown by the solar wind out ahead of the comet as it moved away from the sun. The newly discovered antitail, presumably formed by particles too heavy to be affected by the solar wind, trailed behind the comet. While Kohoutek, named for the Czech-born astronomer who discovered it 437 million miles from the sun, was a scientific success it did not live up to its advance billing as the "comet of the century". Ground observers saw only a smudge in the winter skies instead of the glowing tail which was expected to become brighter as the comet streaked at 250 thousand miles an hour to within 13 million



11 THE LICK OBSERVATORY

In the foreground is the dome of the 120-inch reflecting telescope of the Lick Observatory near San Francisco.


ORBIT OF HALLEY'S COMET
URANUS
JUPITER
SATURN
MARS
EARTH



Three images of the comet Kohoutek.

miles of the sun. Scientists explained that Kohoutek, making its first approach to the inner solar system, flared up briefly and then faded out as it got closer to the sun's heat. Kohoutek again proved the unpredictability of comets.

Meanwhile, plans are progressing for the launch in 1980 of a pair of spacecraft which will slowly fly through the comet Encke during its approach to the sun. Scientific data from these probes will contribute immeasurably to man's understanding of the 100 billion comets, particularly the bearing they may have on the early history of our solar system.

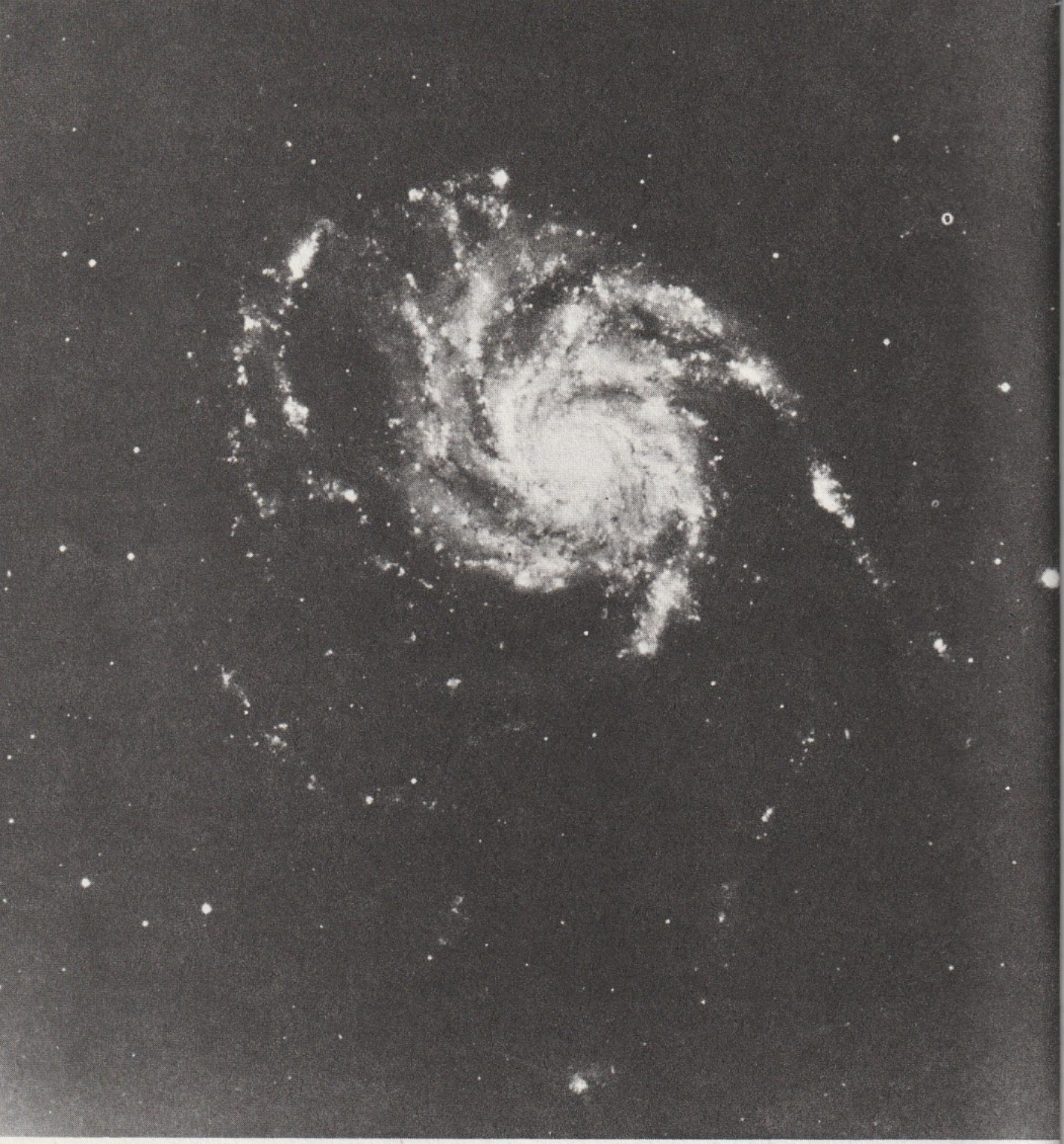
One thing is certain, however, about the unpredictable and mysterious comets—they will be back again. Like clockwork, Halley's comet appears every seventy-six years, and was first recorded as long ago as 87 B.C. Its next performance: 1986.

The Runaway Universe

AT THE LOWELL OBSERVATORY in Arizona, nearly half a century ago, the astronomical spectroscopes (instruments for breaking up the

16. COLORS OF THE SPECTRUM

The spreading of a white beam of light by a prism produces the color spectrum. The reddish beams at right are those of the longest wavelength and are bent the least. Should a light source be moving away from the prism, the light waves would shift toward the red end. This shift, known as the Doppler effect, is employed as evidence for the theory of an expanding universe.



M 101—a spiral galaxy—is made up of millions of stars, located in a central nucleus and along well-defined spiral arms.

light of a star into the rainbow hues of the spectrum) showed conspicuous red shifts of the spectral lines (characteristic dark lines that interrupt or separate the hues of the spectrum) of a few spiral galaxies. The observations marked an epoch in the exploration of the universe. But before we outline the consequences of these early studies of the spectra of spiral galaxies, we should explain the term "red shift".

A nebula in the constellation Cassiopeia. The streak at the top appeared when a meteor passed through the telescopic field of view when the exposure was made.

Also known as Doppler shifts, red shifts were first studied in connection with sound waves. Whether for sound or light, the Doppler shift involves a difference in the apparent frequency of waves when the source is moving past an observer, or when an observer is moving past a stationary source of sound or light.

The most common example of the Doppler shift is the change in pitch of a blasting auto horn as a car goes past the observer. The explanation is that when the source from which the waves are spreading is approaching the observer, the waves are crowded together, so that the wavelengths are shortened, and the note of the auto horn rises in pitch. When the source is receding, the waves are spread farther apart, and the note drops.

The Crab Nebula in the constellation Taurus is a cloud of dust, gas, and meteoric debris. Photographs during the last thirty years show that it is expanding from a central point, a result of the stellar explosion that produced the supernova in 1054.

With light waves from the stars, it is impossible to be sure whether source or observer is moving; it is only the relative velocity of the two that can be measured. Where the light source is relatively approaching or receding from an observer, its spectral lines are displaced to shorter or longer wavelengths respectively by an amount that is directly proportional to the speed of approach or recession. A shift to shorter wavelengths is a shift toward the blue end of the rainbow spread of hues; to longer wavelengths, a shift toward the red end.

Interpreting these shifts as indicating that the light sources are speeding away from the observer, a startling result was deduced. Galaxies were receding at unheard of speeds; this was the message of the red shift. Practically all galaxies were receding from us and from each other with greater speeds than astronomers had ever before measured for stars or nebulae.

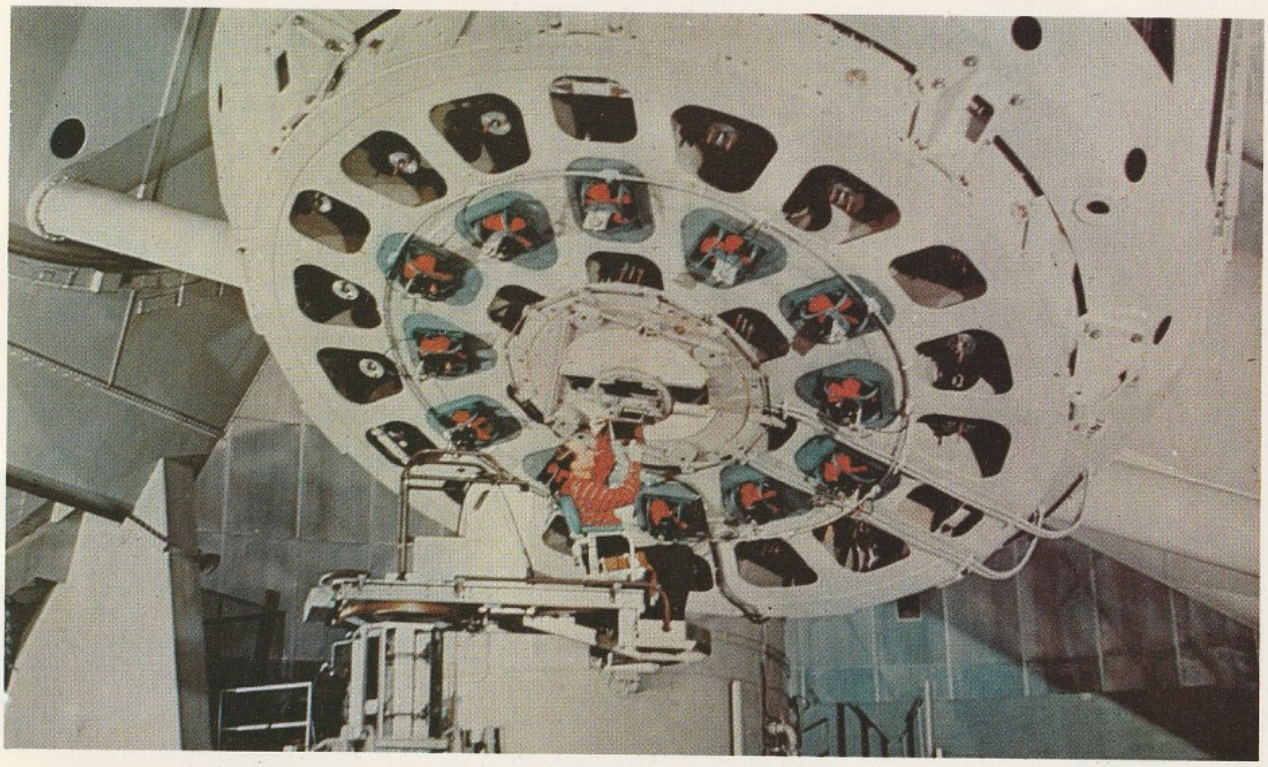
The Arizona finding was confirmed in later years by much work at Mount Hamilton, Mount Wilson and Palomar observatories. Eventually more than 800 galaxies of all types, and located in all directions, were laboriously measured for speed. Red shifts prevailed overwhelmingly. The universe of galaxies was found to be scattering.

Some astronomers at once noted that the bigger the galaxy, the bigger the red shift and the greater the speed. But the faintness of a galaxy is an indicator of its distance—the further away, the fainter, and therefore the speedier. It was soon discovered that an important relation could be set up, a correlation between distance and speed. The actual rate has not been fixed conclusively by astronomers, but it is approximately as follows:

For galaxies at a distance of a million light-years, the speed is thirty miles a second; 300 miles a second for galaxies 10 million light-years away; 3,000 miles a second for galaxies separated by 100 million light-years, and so forth.

New Mystery: Quasars

In 1960, Dr. Maarten Schmidt, at the California Institute of Technology, conducted optical and radio tests on a number of stars believed to be in the Milky Way. He discovered a wide variety of "red shift" measurements and concluded that many of the stars were not in the Milky Way after all, but billions of light-years farther out. The finding shocked the world of astronomy—and has puzzled it for the past



15. UNDERNEATH THE 200-INCH DISC

A technician at one of the three observational points of the Hale 200-inch telescope. Astronomical research relies more on photographic plates than on direct visual observation.

fifteen years. The name given to these bizarre stars is "quasar", short for quasi-stellar radio source.

So far, more than 300 quasars have been identified. The best estimate is that the farthest ones are 12 billion light-years away, making them the farthest objects known. Beyond the quasars—who knows?

Assuming the accuracy of the red shift, on which not all astronomers agree, then those studying quasars are peering about as far into the universe as man possibly can, for it would be impossible to see an object traveling faster than light. They are actually observing through their powerful telescopes light that left the quasars 12 billion years ago and has been traveling at 186 thousand miles a second ever since.

Astronomers do not know the nature of quasars (compact stars), particularly the source of their immense energy, which equals that of more than a billion suns. They think quasars, not unlike youngsters, are just having a good time bouncing around the universe as the nuclei of

young galaxies before settling down. Still others believe that their enormous energy comes from "black holes" in their interiors.

Quasars may be photographed through telescopes because, though they have a diameter only a quarter-billionth that of a galaxy, they may be 100 times as bright. Their brightness may be explained by some sort of unconventional means of producing energy. Some astronomers suggest that quasars are made of materials that are collapsing rapidly, releasing gravitational energy, or that matter and anti-matter are annihilating each other in a blast of stupendous power. A less dynamic theory is that quasars are simply matter expelled from galaxies.

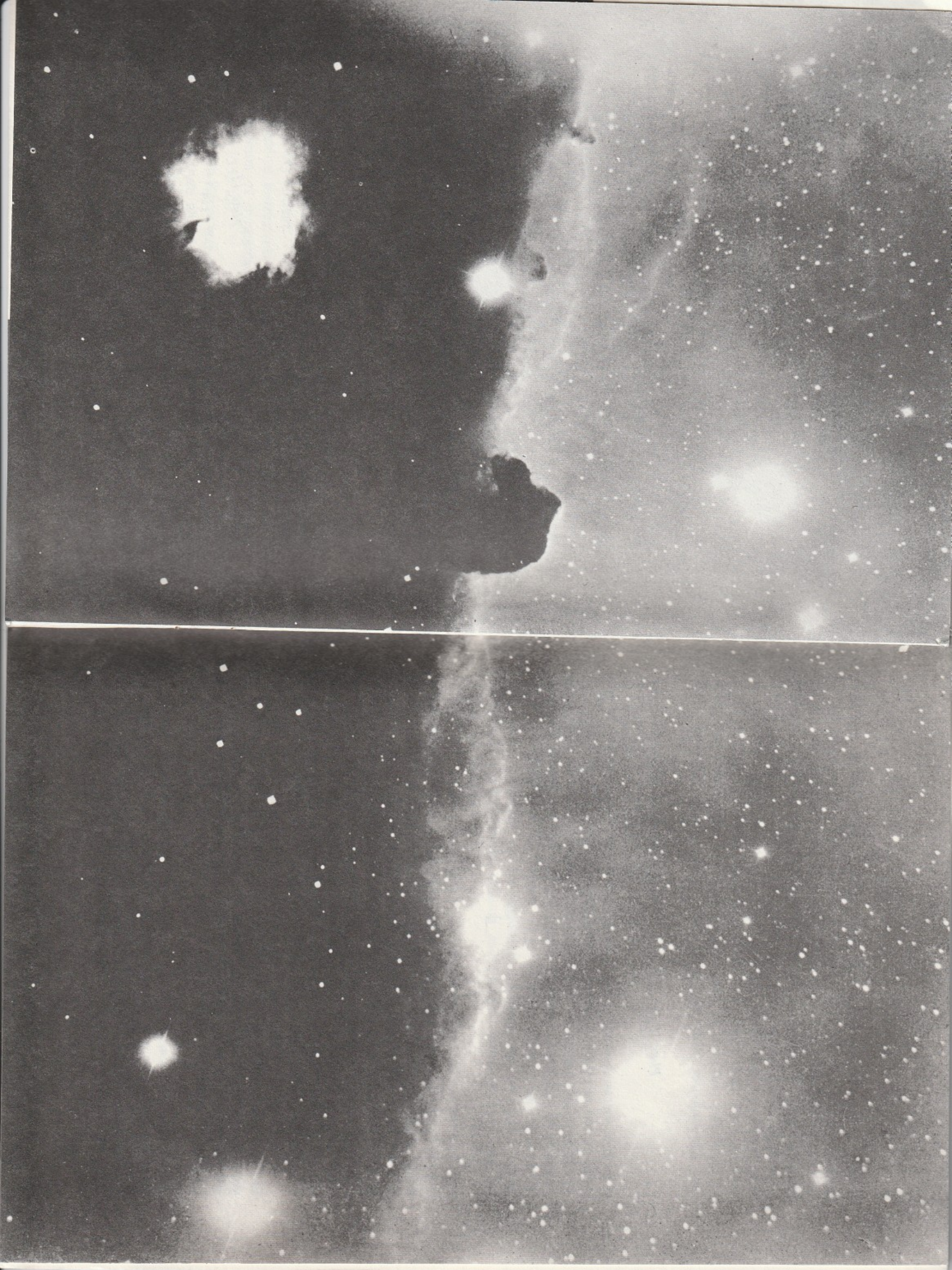
One thing is certain: Quasars are an exciting mystery. The secrets they may hold are important: How do they generate their enormous radiant energy? How large are they? What is their structure? Mainly, what clues do they hold to the secrets of the birth of the universe?

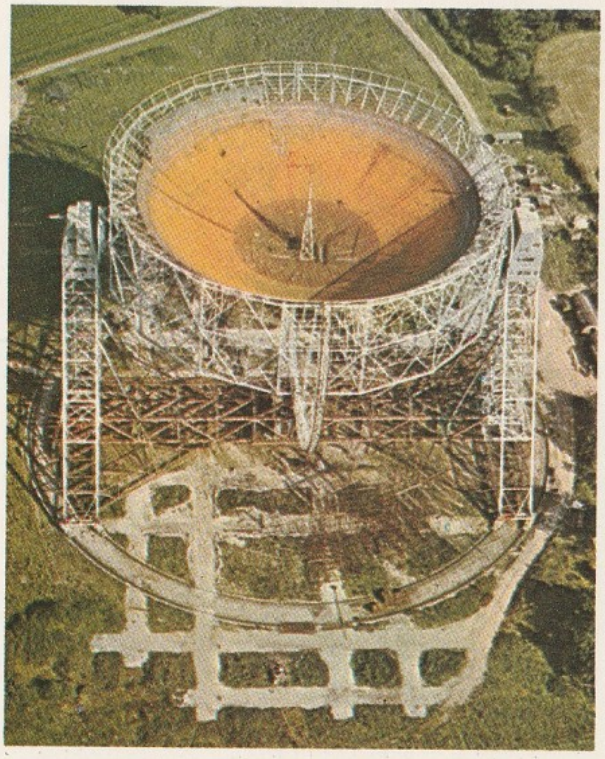
Another Mystery: Pulsars

FEW DISCOVERIES IN THIS CENTURY have so tantalized and puzzled scientists as the "pulsars"—or celestial sources of pulsing radio emissions. In 1967, the first pulsars were discovered by British radio astronomers at Cambridge University. These mysterious stars were pulsating their radio waves into space thirty-three times a second. Nearly 100 pulsars have been identified—beating so regularly that you could set your watch by them.

George Ellery Hale, founder of the Hale Observatories at Mount Wilson and Mount Palomar. The world's largest telescope, the 200-inch reflector at Mount Palomar, California, was named in his honor. He died in 1938, nine years before the Hale telescope was put into operation.

17. GEORGE ELLERY HALE





18. RADIO TELESCOPE

This is one of the world's largest radio telescopes, at Jodrell Bank in England. The dish-shaped antenna is 250 feet in diameter and receives energy in radio wavelengths from many sources. Radio waves can be received at any time of day or night and even when it is cloudy.

The theory now is that the signals are the natural oscillations of dying stars that had shrunk by gravitational contraction into white dwarfs, or neutron stars. Neutron stars are incredibly dense bodies of tightly packed neutrons, that supposedly are remains of supernovae.

Pulsars are unimaginably tiny. If they were any larger they would be torn about by the force of their own spinning, at the rate of 100 times a minute. A pulsar ten miles across has a density so great that a spoonful size of it would weigh as much as Manhattan Island.

A question that pulsars may help to answer involves the mystery of the so-called missing mass. This mystery arises from the fact that if you were to count up everything in the heavens that shines, you would get no more than three per cent of the mass needed to make up the universe.

(*Preceding pages*) The great Horse-head nebula is the constellation Orion. The dark mass of the Horse-head is a cloud of gas and dust obscuring more distant stars. The light points are stars situated in front of the dark nebula.

Where is the missing ninety-seven per cent? One theory is that it is hidden throughout the universe in thin, hot clouds of gas. Another is that the missing mass is bound up in the gas and dust of coma star clusters, a term that describes spheres of as many as 1,000 galaxies bound together. Still a third theory—one now getting much attention—is that the missing mass is lost in dead stars that no longer give light, in the so-called black holes—that is, stars that have evolved from the pulsar into an even denser state of collapse, so dense, in fact, that they don't permit light to escape their gravitational pull.

Is There Life Out There?

THE EXCITING ASTRONOMICAL DISCOVERIES of the past decade add up to a high probability that intelligent life exists elsewhere in the universe. That is the view of many eminent scientists, including the special Astronomy Committee of the prestigious National Academy of Sciences. The committee, in its report, cites as support for this probability the recent discovery of life-suggestive chemicals in interstellar space, as well as the mysterious quasars and pulsars—although these are not deemed to be inhabited.

What the quasars and pulsars do suggest is "general cosmic violence" being involved in the formation of all stars, and perhaps the existence of planetary systems around many of them. "Our civilization is within reach of one of the greatest steps in evolution; knowledge of the possible existence, nature and activities of independent civilizations in space," says the committee in its report. "At this instant, through this very document, are perhaps passing radio waves bearing the conversations of distant creatures—conversations that we could record if we but pointed a radio telescope in the right direction and tuned to the proper frequency."

It was not so many years ago that the idea of intelligent life elsewhere in the universe was scoffed at as pure drivel. That is no longer true. The optimism expressed by the eminent scientists of the National Academy is sure to spur the construction of giant radio receiving arrays and other facilities to help prove that there truly is life out there.

Indeed, we may be on the verge of one of science's most important and profound discoveries. And perhaps one of you, now reading these pages, may some day devise a new picture of the universe that will be worthy of its grand complexity and beauty.

Glossary of Useful Terms

Absolute magnitude. Brightness a star would seem to have if it were ten parsecs (32.6 light-years) from earth.

Astronomy. Science dealing with celestial bodies.

Astronomical unit. The mean distance from earth to the sun—92.9 million miles.

Celestial mechanics. Science dealing with the motion of heavenly bodies.

Celestial sphere. Imaginary sphere on which the stars appear to be located.

Constellation. Group of stars described as forming a pattern.

Cosmology. Study of the universe and its origins.

Doppler shift. The apparent change in wavelength in connection with the relative motion of the emitter and the observer. Sources of light approaching the observer have spectrum lines shifted toward violet; those receding shift toward red.

Eclipse. Occurring when the light of one celestial body is cut off from the observer by a second body passing between them.

Galaxy. A large system of stars, dust and gas isolated from similar systems in space. Our galaxy is called the Milky Way.

Gravitation. The universal attractive force which all matter exerts on other matter.

Intrinsic brightness. The true brightness of a star; the property measured by absolute magnitude.

Light-year. Equivalent to the distance traveled by light in one year—about 6 trillion miles.

Luminosity. The brightness of a star as compared to the brightness of the sun, which has a luminosity rating of 1.

Nebula. A cloud of interstellar matter, often revealed because it is illuminated by a bright star.

Parsec. Distance at which a star would have the *par*allax of one *sec*ond of arc—3.26 light-years.

Period. Time required for a single revolution of a planet around the sun.

Retrograde motion. The backward or apparent westward movement of planets as viewed against the background of "fixed stars".

Star time (*sidereal time*). Time that is measured with respect to the earth's rotation relative to the stars.

Universe. The entire cosmos.

Zenith. The point on the celestial sphere directly above the observer.

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